QUALITY ASSURANCE SAMPLING PLAN

FOR

GRANTS MINERAL BELT
STRUCTURES ASSESSMENT
CIBOLA AND MCKINLEY COUNTIES, NEW MEXICO

Prepared for

U.S. Environmental Protection Agency Region 6
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1. INTRODUCTION

Weston Solutions, Inc. (WESTON®) EPA Region 6 Superfund Technical Assessment and Response Team (START-3) Contractor has been tasked by the U.S. Environmental Protection Agency (EPA) Region 6 Prevention and Response Branch under Contract No. EP-W-06-042 and Technical Direction Document (TDD) No. TO-0005-09-02-01 to conduct assessments at residences impacted by uranium mining and milling operations in the Grants Mineral Belt, including the Ambrosia Lake, Laguna, and Marquez mining subdistricts located in Cibola and McKinley Counties, New Mexico. The Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) number assigned to the site is NMN000606847. A document outlining the protocols to be used on this project has been developed (Appendix A). START-3 has prepared this Quality Assurance Sampling Plan (QASP) to describe the technical scope of work (SOW) to be completed as part of the removal assessment. This Quality Assurance Sampling Plan is a dynamic document which may be amended as required by site conditions.

1.1 PROJECT OBJECTIVES

START-3 is providing technical assistance to EPA Region 6 for the performance of the removal assessment and to collect the data necessary to support the EPA determination that the site presents a threat to public health or welfare of the United States or the environment in accordance with *40 Code of Federal Regulations (CFR) 300.415*. The objectives of the project are to take readings using direct-reading radiation instruments and to collect soil and air samples to determine if identified site-related contaminants are present on the properties sampled.

The objectives of the QASP will be achieved by evaluating field and laboratory analytical results obtained during field activities. Direct reading instruments and soil samples are to be used to ascertain Radium-226 concentrations for comparison to a risk-based action level of 15 millirem per year. Radon samples will be collected for comparison to EPA action levels of 4 picocuries per Liter (pCi/L).

1.2 PROJECT TEAM

The Project Team will consist of David Bordelon, the START-3 Deputy SOW Manager; Robert Sherman, Project Team Leader (PTL) and Field Safety Officer (FSO); Bob Schoenfelder, Certified Health Physicist (CHP); and other START-3 personnel as necessary.

The PTL will be responsible for the technical quality of work performed in the field during the site activities and will serve as the START-3 liaison to EPA Region 6 in the field. The PTL, with the concurrence of EPA, will direct START-3 in obtaining access to residences, determining the locations for sample collection in the field, in collecting samples as necessary, in maintaining data in SCRIBE and in a site-specific GIS project, and in verifying the sample documentation. The CHP will work remotely and will consult with on-site staff as needed. The START-3 FSO will be responsible for providing overall site health and safety support.

1.3 QASP FORMAT

This QASP has been organized in a format that is intended to facilitate and effectively meet the objective of the removal assessment. The QASP is organized as follows:

- Section 1 – Introduction
- Section 2 – Site Background
- Section 3 – Sampling Approach and Procedures
- Section 4 – Analytical Methods
- Section 5 – Data Validation
- Section 6 – Quality Assurance

Figures are provided as separate files. Appendices are attached with the following information:

- Appendix A   Site-Specific Data Quality Objective Table
- Appendix B   Uranium Home Site Assessment Protocol
- Appendix C   EPA ERT and WESTON Standard Operating Procedures

2. SITE BACKGROUND

Information regarding the site location, description, and site history are included in the following subsections.

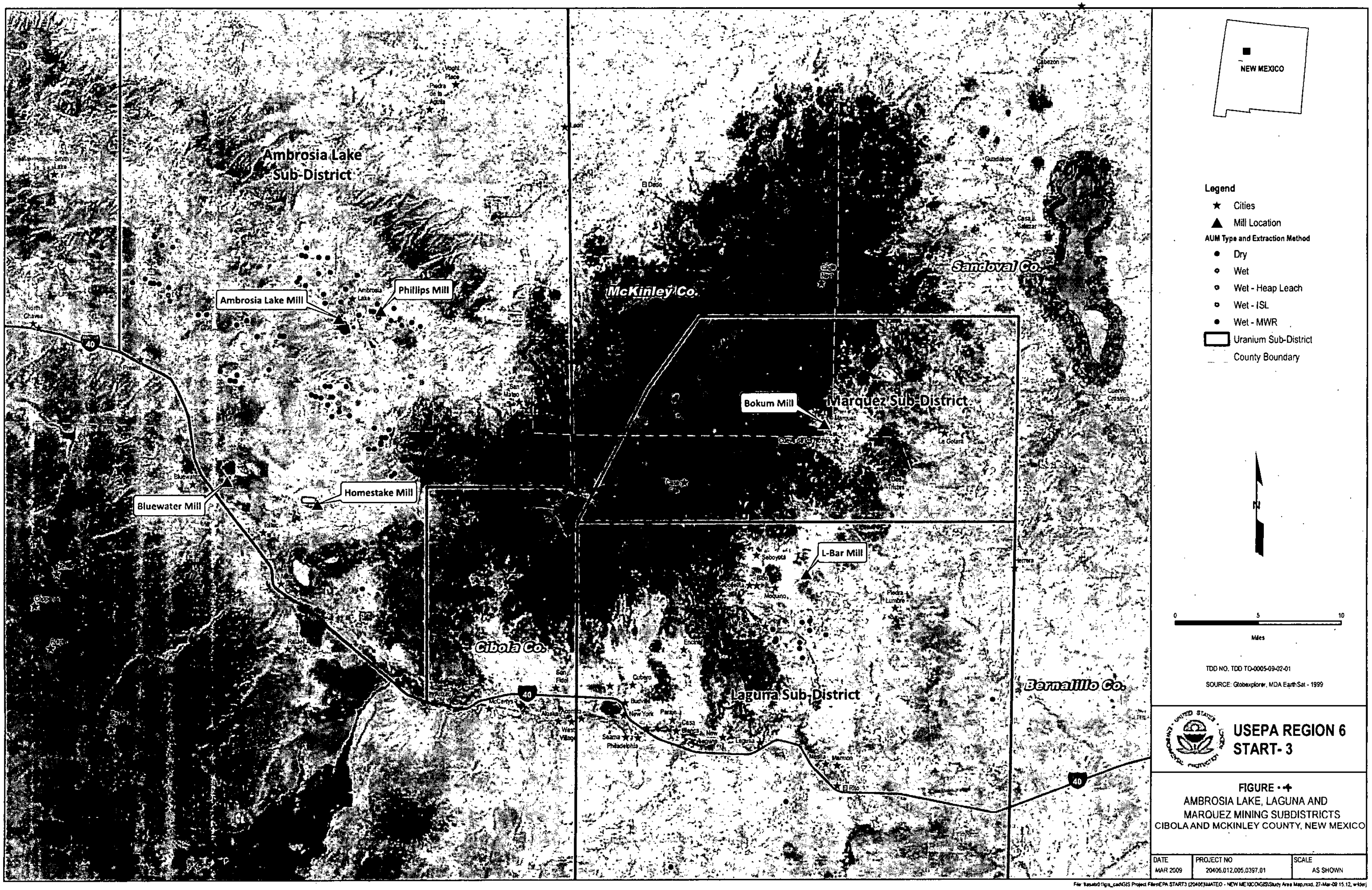
2.1 SITE LOCATION AND DESCRIPTION

The San Mateo Creek Basin portion of the Grants Mineral Belt is located in Cibola and McKinley counties in northwestern New Mexico, near the town of Grants. This area was the site of extensive uranium mining from 1950 until the early 1980s. During this time the economy of the region changed from agriculture to uranium mining and uranium ore processing. Most uranium mining activities stopped in the recession of 1982-1983. The San Mateo Creek Basin is composed of the Ambrosia Lake, Laguna, and Marquez mining subdistricts (Figure 2-1).

2.2 SITE HISTORY

In northwestern New Mexico, houses were traditionally made with stone walls using mud as mortar, with mud and sand stucco. Some residents may have used the tailings piles from uranium mines and mills as a source of building materials for new houses or to repair old houses. These rocks and dirt from the tailings piles, as well as timbers and scrap metal, may have contained radioactive materials that have been incorporated into the structure of the houses. Additionally, radioactive materials may have been brought into the yards or deposited in the soils near these houses.

In 2007, EPA Region 9 began a project in coordination with the Navajo Nation to investigate residences on the Navajo Indian Reservation located in parts of Arizona, New Mexico, and Utah for radioactive contamination caused by uranium mining on the reservation. In 2009, EPA Region 6 initiated a similar project to investigate radioactive contamination in residences near uranium mining and ore processing areas outside of the Navajo Reservation in the San Mateo Creek Basin area of northwestern New Mexico. These areas will include non-Navajo lands adjacent to the eastern boundary of the Navajo Reservation with public and/or private ownership, privately-owned lands, and lands owned by the Laguna and Acoma Pueblos.



NEW MEXICO
Legend
Cities
Mill Location
AUM Type and Extraction Method
Dry
Wet
Wet - Heap Leach
Wet - ISL
Wet - MWR
Uranium Sub-District
County Boundary
Ambrosia Lake Sub-District
Ambrosia Lake Mill
Phillips Mill
Bluewater Mill
Homestake Mill
McKinley Co.
Sandoval Co.
Bokum Mill
Marquez Sub-District
L-Bar Mill
Cibola Co.
Laguna Sub-District
Bernalillo Co.
40
0
5
10
Miles
TDD NO. TDD TO-0005-09-02-01
SOURCE: Globexplorer, MDA EarthSat - 1999
USEPA REGION 6
START- 3
FIGURE
AMBROSIA LAKE, LAGUNA AND
MAROUEZ MINING SUBDISTRICTS
CIBOLA AND MCKINLEY COUNTY, NEW MEXICO
DATE
MAR 2009
PROJECT NO
20406.012.005.0397.01
SCALE
AS SHOWN

3. SAMPLING APPROACH AND PROCEDURES

The monitoring and sampling procedures for this project will be consistent with the protocols developed by EPA Region 6, provided as Appendix B. The specific field investigation activities that will be conducted during site sampling are presented in the following subsections. Sampling procedures and sample locations are also included.

3.1 OVERVIEW OF MONITORING/SAMPLING ACTIVITIES

The removal assessment approach will consist of monitoring for gamma radiation using direct-reading instruments, collecting air samples for radon analysis, and collecting samples of soil and other miscellaneous media for laboratory gamma spectroscopic analysis. The removal assessment will also analyze soil samples for total uranium to address chemical (non-cancer) toxicity.

Each residence will have three radiological action levels: Radon, Derived Concentration Guideline Level (DCGL), and gross alpha. The action level for Radon will be 4 picoCuries per liter (pCi/L). The DCGL will be calculated for each individual residence as outlined in Section 3.2.1. The DCGL will be based on a dose of 15 millirem per year (mrem/y), which represents a cancer risk of $3x10^{-4}$ (EPA, Office of Solid Waste and Emergency Response, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, August 22, 1997). The action level for gross alpha will be 20 disintegrations per minute per 100 square centimeters (dpm/100 cm^2). The air samples will be delivered to the participating laboratory for Radon analysis. The soil and miscellaneous material samples will be delivered to the participating laboratory for gamma spectroscopy.

The total concentration of uranium in soil will be investigated using a non-cancer screening level of 230 milligrams per kilogram (mg/kg).

Sample data management will be conducted using EPA Scribe Environmental Sampling Data Management System (SCRIBE) software.

3.1.1 Data Quality Objectives

The objective of the sampling activities described in this QASP is to delineate the contaminants of concern within the assessment areas. To accomplish this, the following data quality objectives (DQOs) have been established:

- Determine if the Total Effective Dose Equivalent (TEDE) exceeds 15 millirem per year by taking readings of gamma radiation and collecting soil samples.
- Collect air samples inside the house to determine if the Radon-222 concentrations exceed 4 picoCuries per liter.
- Collect surface soil samples from the yard to determine if Uranium concentrations exceed 230 mg/kg.
- Collect wipe samples from interior surfaces to determine if gross alpha activity exceeds 20 dpm/100 cm^2.

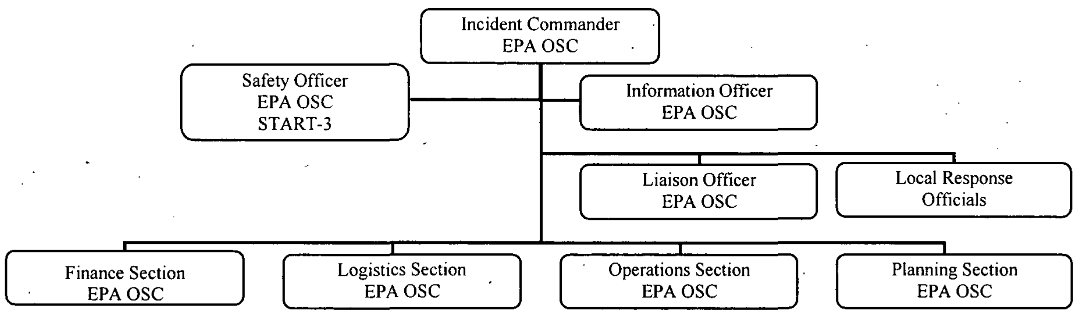
The DQOs presented in Appendix A were developed using the seven-step process set out in the *Guidance for Quality Assurance Project Plans EPA QA/G5.*

3.1.2 Field Activities Review Meeting

Prior to mobilizing to the site, the START-3 PTL will conduct a meeting in the WESTON office with the entire field team to familiarize the team with the project scope of work, to discuss the planned field activities and roles and responsibilities, and to review the project Health and Safety Plan (HASP) and other relevant START-3 and EPA operating procedures. This meeting will be conducted prior to any site activities. The field team will also be briefed on the project budget and expense reporting responsibilities.

3.1.3 Incident Command System and Health and Safety Implementation

START-3 will provide planning functions consistent with activities and responsibilities of the Incident Command System (ICS). At the beginning of each operational period, a daily operation meeting will be held in the command post to discuss objectives of the operation period, division assignments, field instrumentation calibration and use, and health and safety. Every afternoon a planning meeting will be conducted to develop a daily Incident Action Plan (IAP) for the next operation period. As part of ICS, local response officials including the fire and police departments and the local hospital will be notified to preplan for emergencies that may occur during the course of the removal action. The ICS organization chart established for this site is as follows:



The removal assessment field activities will be conducted in accordance with the site-specific Health and Safety Plan (HASP).

START-3 will conduct all site activities in Level D personal protective equipment (PPE) as stated in the site HASP. The FSO will be responsible for implementation of the HASP during the removal assessment activities. In accordance with the START-3 general health and safety operating procedures, START-3 personnel will drive the route to the hospital (site-specified in the HASP) prior to initiating sampling activities.

3.1.4 Mobilization and Command Post Establishment

The START-3 field team will mobilize the equipment required for the removal assessment from the WESTON Regional Equipment Store (RES) warehouses located in Houston and Dallas, Texas, as necessary. A Command Post will be located in the town of Grants, New Mexico to be used as a base of operations and to meet with the public.

3.1.5 Access to Residential Properties

The START-3 field team will obtain access agreements before conducting work at any residence. START-3 will not go inside of the houses unless the homeowner or an authorized representative is present.

3.2 SAMPLING/MONITORING APPROACH

This project will address both the radiological toxicity of uranium and its daughter elements and the chemical toxicity of uranium. Sections 3.2.1 through 3.2.8 outline the screening and sampling procedures that will be used to investigate radiological contamination. Section 3.2.9 outlines the process to investigate chemical toxicity of uranium. The investigation will be conducted in two phases. Phase I will include gamma screening and soil sampling in the yard surrounding residential structures. Phase II will include indoor radiation surveys and radon sampling.

START-3 will work with the EPA-OSC and the property owners to determine which structures will be included in the Phase II. In general, Phase II assessment will be conducted in homes in which elevated readings are detected in the yards or in homes where the residents indicate that materials from mines and/or mills were used in the structure. Radon sampling will be conducted in all homes in the villages of Paguate, Bibo, Seboyeta, and Moquino because these villages are built on top of extensive uranium-containing ore bodies.

Residential information sheets will be sent to residents in the towns of Grants, Milan, Toltec, Bluewater, San Rafael, and Lobo Canyon subdivision. The residential information sheets e will be seeking information about any materials that originated at one or more of the uranium mines or mills that may have been used in the construction or remodeling of the individual residential structure(s). Other information of interest will include, the use of material originating from the uranium mines or mills that have been used in property fencing, landscaping, souvenir displays in the home or landscape and/or the storage of any of these materials for future use. The EPA OSC will evaluate the information in the residential information sheets to determine if assessment activities are warranted at a residence.

3.2.1 Calculating the DCGL

As outlined in the Uranium Home Site Assessment Protocol developed for this assessment (Appendix B), the action levels for this project for soils and building materials will be based on risk. The action level will be based on a dose of 15 millirem per year (mrem/y), which represents a cancer risk of $3x10^{-4}$. The DCGL can be calculated by using a computer program to estimate the TEDE from the concentrations of radionuclides in the soil.

START-3 has used RESidual RADioactivity (RESRAD) software to calculate TEDE from soil radionuclide concentrations, although many other programs are available. The RESRAD code was developed by Argonne National Laboratory for the U.S. Department of Energy and calculates the Effective Dose Equivalent (EDE) from each radionuclide through each pathway. The six pathways evaluated in this protocol development include direct exposure, inhalation of air particulates, and ingestion of plant foods, meat, milk, and soil. Default values are provided for parameters used by the code. Different exposure scenarios can be specified by adding or suppressing pathways and modifying usage or occupancy factors. RESRAD essentially mimics a classic Site Conceptual Model, taking into account all pathways of exposure. Using the default parameters, START-3 used RESRAD to calculate a DCGL of 0.9 pCi/g of Radium 226 (Ra-226). However, the default parameters for RESRAD assume that the residents will ingest approximately 350 pounds of home-grown fruit, vegetables, and grain per year (Table 3-1). Based on prevailing conditions in the area and using site-specific input parameters that reduce the amount of home-grown fruits and vegetables to 4.4 pounds per year, START-3 used RESRAD to calculate a DCGL of 2.5 pCi/g of Ra-226 for this project.

START-3 will use a DCGL of 2.5 pCi/g of Ra-226 as the site-specific default action level. START-3 will verify that the default conditions exist at a residence and make note of any signs of home-grown food products. If a vegetable garden is noted, START-3 will interview the residents to determine the type and quantity of produce grown and eaten. START-3 will run the RESRAD software with residence-specific parameters and determine a new DCGL if actual conditions and practices at the residence are significantly different than the site-specific default values selected for this project. Table 3-1 presents both the RESRAD default values and the site-specific default values.

Table 3-1

Selected Input Parameters for RESRAD Analyses

Parameter	RESRAD Default Value	Site-Specific Default Value
Thickness of contaminated soil	2 meters (~ 6 feet)	15 centimeters (~ 6 inches)
Area of yard	10,000 m^2 (~ 2.5 acres)	4,000 m^2 (~ 1 acre)
Home-grown fruits, vegetables, and grain consumed annually	160 kilograms (~ 350 pounds)	2 kilograms (~4.4 pounds)
Home-grown leafy vegetables consumed annually	14 kilograms (~ 31 pounds)	2 kilograms (~4.4 pounds)

3.2.2 Defining Background

Before the assessment begins, background areas will be identified and measured. A background area is a non-impacted area representative of the properties to be assessed with similar physical, biological, chemical, and radiological characteristics against which readings at residential sites can be compared. Background areas will be selected by location, gamma radiation level, and geological formation. To establish a background area, START-3 will collect soil samples to be analyzed for Ra-226 and conduct stationary 1-minute gamma radiation count rate readings above each sample location using a 2-inch by 2-inch sodium iodide detector (2x2 NaI). For statistical modeling, a minimum of 20 samples and measurements will be collected for a background location, and at least one background area will be established for each group of residences in the same area.

Background locations will be as close as practical to the houses to be assessed. Multiple background locations may have to be established if houses are assessed in different areas.

3.2.3 Empirical Measurement Verification

The U.S. Department of Energy (DOE) maintains radiation instrument calibration facilities in Grand Junction, Colorado that provide a means to collect instrument measurements under controlled conditions and to convert from concentrations of radioactive material in the soil to a reading on a 2x2 NaI detector. These facilities were originally developed to calibrate gamma measuring instruments used in uranium exploration and are also suitable for calibration of instruments used for remedial action measurements, specifically, in-situ assays for natural radionuclides. These calibration facilities were constructed by enriching a concrete mix with uranium ore, monzanite sand, and/or orthoclase sand.

The facilities most applicable to this project are the large area pads, located at the municipal airport in Grand Junction. These concrete pads measure 30 feet by 40 feet by 1.5 feet thick, and are therefore representative of a uniform plane of contaminated soil.

Table 3-2
Calibration Pad Concentrations in Grand Junction, Colorado

Pad Designation	Concentration (pCi/g)[a]		
	Ra-226	Th-232	K-40
W1	0.82 ± 1.02	0.67 ± 0.10	12.67 ± 0.72
W2	1.92 ± 1.54	0.87 ± 0.12	45.58 ± 1.82
W3	1.70 ± 1.38	4.92 ± 0.26	17.07 ± 0.82
W4	12.07 ± 5.64	1.04 ± 0.12	17.56 ± .098
W5	8.36 ± 3.52	1.91 ± 0.16	34.68 ± 1.46

Note: [a] Uncertainties are 95 percent confidence level.

In addition to the calibration facilities in Grand Junction, Colorado, DOE maintains similar but smaller radiation instrument calibration pads in Grants, New Mexico. These concrete pads measure 42 inches in diameter by 24 inches in thickness, and also represent a uniform (but smaller) plane of contaminated soil.

Table 3-3
Calibration Pad Concentrations in Grants, New Mexico

Pad Designation	Concentration (pCi/g)[a]		
	Ra-226	Th-232	K-40
GPK	0.58 ± 0.82	0.01 ± 0.06	51.53 ± 1.46
GPL	87.78 ± 14.32	0.50 ± 0.10	15.58 ± 1.02
GPH	375.74 ± 45.14	0.61 ± 0.10	15.93 ± 1.62
GPT	6.57 ± 3.14	30.23 ± 0.80	14.94 ± 1.02
GPB	0.0 ± 0.3	0.0 ± 0.3	0.0 ± 0.1

Note: [a] Uncertainties are 95 percent confidence level.

Prior to beginning the home assessments, START-3 will bring the 2x2 NaI detectors to the calibration facilities in both Grand Junction, Colorado and in Grants, New Mexico to obtain calibration curves. Instrument-specific calibration curves will be developed to correlate the concentration of Ra-226 in the soil to the readings on the 2x2 NaI detectors.

3.2.4 Surface Soil Screening

For residences surrounded by yards, START-3 will conduct screening throughout the whole yard, or a maximum area of one acre. For residences situated on more than one acre, START-3 will determine the area to be investigated using professional judgment in coordination with the EPA OSC, taking into account areas closest to the houses and areas that appear to be used the most. If a home vegetable garden is located on the property, START-3 will include the garden in the area to be screened.

START-3 will conduct gamma radiation scanning throughout the yard using a 2x2 NaI detector in conjunction with a Global Positioning System (GPS) unit. The detector will be mounted on a cart 15 inches above the surface soil. The cart will be pushed on transects at approximately 1 to 2 feet per second from one end of the property boundary to another. Transects will be separated by no more than 40 inches to provide 100 percent coverage of the surface soil within the property boundary. Debris, vegetation, structures, or other objects will not be moved, and the survey will be conducted around such obstacles.

Additionally, one-minute stationary readings will be made with the 2x2 NaI detector 15 inches above ground level at 20 evenly spaced locations throughout the yard at a typical residence. The locations of the one-minute readings will be documented using the GPS unit.

3.2.5 Soil Sampling

If in-situ screening of the yard with the 2x2 NaI detectors reveals readings above a 14,000 counts per minute (cpm) threshold, START-3 will collect grab soil samples to verify the contamination. Prior to sample collection, a 2x2 NaI detector or a Ludlum Model 19 micro-R radiation meter will be utilized by field personnel around the areas with readings above 14,000 CPM in an attempt to pinpoint the smallest possible area from which these readings emanate, and to eliminate the possibility that these readings emanate from non-soil objects such as rocks, petrified wood, timbers, etc. Where readings above the threshold appear to emanate from movable, non-soil objects, field personnel will move the object and re-screen the revealed soil underneath with the 2x2 NaI detector to determine the location's merit as a possible soil sample location. The 14,000 cpm threshold may be changed to reflect the backgrounds of specific areas as needed.

Additional soil samples may need to be obtained from residential yards that demonstrate a likely average concentration that is close to the DCGL. The final number and location of the samples from each yard will be determined by consultation with the CHP and the EPA OSC and will collected at a later date.

Samples will be collected according to Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) guidelines, except that sample locations will be biased rather than randomly placed. The soil samples will be collected from the top 6 inches of soil and will be submitted with a completed chain-of-custody form to a qualified laboratory for gamma spectrometry analysis.

The soil samples will be collected in general accordance with EPA/ERT SOP. Relevant observations and information will be recorded in the field logbook. Samples will be collected utilizing dedicated plastic scoops to reduce the potential for cross-contamination between intervals and locations. The samples will be placed into quart-size or larger plastic bags, and then homogenized. Foreign material such as vegetation, large rocks and pebbles, etc. will be removed from the sample and placed back on the property.

Samples will be analyzed for Radium-226 by gamma spectrometry by a subcontracted laboratory capable of performing radiological analyses.

3.2.6 Indoor Radiation Surveys

Indoor gamma radiation screening will be conducted in buildings that are used as a residence or structures related to a residence that are frequently occupied as a workspace. START-3 will work with the EPA-OSC and the property owners to determine which related structures will be screened. In general, indoor screening will be conducted in homes in which elevated readings are detected in the yards or in homes where the residents indicate that materials from mines and/or mills were used in the structure. START-3 will conduct a gamma radiation screening and a static dose rate measurement in each room of the residence/related structure as described in the following sections.

3.2.6.1 Static Dose Rate Measurement

START-3 will conduct a static dose rate measurement in the two largest rooms in the residence/related structure with a Pressurized Ion Chamber (PIC). The PIC will be placed in the middle of the room with the center approximately one meter (39 inches) above the floor, with all furniture moved away to the extent practical. The PIC will be operated in accordance with the SOP for the PIC and allowed to measure for 5 minutes. A 2x2 NaI detector will be cross-calibrated to the PIC during the static dose measurements prior to conducting the gamma radiation screening surveys in each room of the residence/related structure.

3.2.6.2 Gamma Radiation Screening

Interior gamma radiation screening will be conducted using a 2x2 NaI detector while crossing the floor and walking around the circumference of each livable room in the residence/related structure, excluding rooms such as closets, storage rooms, and utility rooms. Instrument count rates will be observed and the locations of any anomalously high count rates that indicate exposure rates greater than 2.5 microRoentgens per hour (μR/hr) above background (1900 cpm above background) will be recorded in a logbook along with an estimate of the size of the area where the elevated readings are noted. At a minimum, START-3 will record the range of readings in each room that are below the 1900 cpm above background rate.

START-3 will conduct screening in each room, making two transects across the room and along each wall. The detector will be held approximately 1 foot above the floor as the surveyor walks across the room at a rate of 1-2 feet per second from one wall to the opposite wall. The surveyor will then repeat the procedure walking between the other two walls.

Each wall will be screened at a height halfway between the floor and the ceiling. The detector will be held at this height approximately 1 foot from the wall and moved along the wall at a rate of 1-2 feet per second. Any locations that demonstrate exposure rates greater than 1900 cpm above background will be recorded and investigated further, in an attempt to determine the source.

If gamma readings greater than 1900 cpm above background are detected inside of the residence/related structure in localized areas indicating potential surface contamination, START-3 will collect a wipe sample from the surface in the area of the most elevated reading. The wipe sample is collected by wiping a 100 square centimeters (cm^2) area of the surface with a porous paper filter or maslin wipe. The sample is placed into an individual envelope or plastic bag. The wipe sample will be counted on a portable gross alpha tray counter or sent to an analytical laboratory for gross alpha analysis. Results in excess of 20 dpm/100 cm^2 will indicate potential contamination from uranium mine or mill site materials. If isotopic results are determined by the reviewing health physicist to determine the need for remediation at a residence, wipe samples may additionally be analyzed by gamma spectrometry.

3.2.7 Radon Sampling

START-3 will work with the EPA-OSC and the property owners to determine which structures will be sampled for radon. In general, radon sampling will be conducted in homes in which elevated readings are detected in the yards or in homes where the residents indicate that materials from mines and/or mills were used in the structure. However, after reviewing historical mining data and consulting with the New Mexico Bureau of Geology and Mineral Resources, it appears that the villages of Paguate (Laguna Pueblo), Bibo, Seboyeta, and Moquino are built on top of extensive uranium-containing ore bodies. Based on this information, the EPA-OSC has decided to collect radon samples from all residences in these areas as part of the Phase I data collection effort.

Radon samples will be collected from inside of the residence/related structure using charcoal canisters placed in two rooms per structure and left in place for a period of 5 to 7 days. The detector will be placed in the lowest lived-in level of the structure, and the owner will be instructed to keep outside doors and windows closed as much as possible during the test and not to move or handle the monitors. START-3 will return at the end of the monitoring period to collect the monitors, seal them according to the laboratory's instructions, and send them with necessary documentation to the laboratory for analysis.

3.2.8 Radiological Data Interpretation

Radiological data collected from each home-site will be compared to three primary criteria: 1) does the TEDE, excluding the contribution from radon and its progeny, exceed 15 mrem/year, 2) does the Rn-222 concentration in the dwelling exceed 4 pCi/l, or 3) does the gross alpha activity of wipe samples exceed 20 dpm/100 cm^2. If any of these criteria are exceeded, the home-site would be considered for a Removal Action.

Comparison of site data to the TEDE criterion requires that a qualified health physicist review all of the site data and compare the actual site conditions to the assumptions that were used in developing the DCGL using RESRAD. If actual site conditions are materially different than those assumed in RESRAD, a revised DCGL will be calculated to which the site will be compared. The health physicist will estimate the TEDE for the residents based upon the average Ra-226 soil concentration outdoors, the summation of the contribution from localized elevated concentrations (hot spots) of Ra-226 outdoors, the external exposure rate indoors, and any other contributors to the TEDE that are identified during the survey. If the TEDE exceeds 15 mrem/yr, the health physicist will meet with the EPA OSC to recommend further investigation, abatement, or mitigating techniques that could reduce the TEDE to an acceptable level.

3.2.9 XRF Soil Screening

In each yard, START-3 will conduct soil screening to address the chemical toxicity of uranium. Each yard will be divided into two 10-point grids. The two 10-point grids will correspond to the 20 evenly spaced points used for 1-minute readings as discussed in Section 3.2.4. Where practical, grids will encompass discrete areas of the yard (e.g., side yard, backyard, etc.). The 10 point composite samples exceed the minimum of 9 points recommended for grids larger than 10,000 square feet by the Superfund Program Representative Sampling Guidance (EPA 540/R-

95/141). While the guidance document recommends developing square grids, the grids on this project will be constrained by the size and shape of the yard as well as obstacles such as trees and shrubs, large rocks, dog houses, children's play equipment, and old vehicles within the yard. The locations of each aliquot will be documented by GPS.

START-3 will collect a 10-point composite surface soil sample from each grid. The sample will be collected into a plastic bag for homogenization. The composited soil in the bag will be analyzed with a field-portable X-Ray Fluorescence analyzer (XRF) for uranium. A minimum of ten percent of the samples will be transferred into jars and sent to an analytical laboratory for analysis via EPA SW-846 method 6020. The results of the XRF and laboratory analyses will be compared to the residential soil screening level of 230 mg/kg.

3.2.10 Investigation-Derived Wastes

Attempts will be made to minimize investigation-derived waste (IDW) during this investigation by utilizing disposable sampling equipment. Any IDW generated will be handled in accordance with EPA Guidance Document EPA/540/G-91/009, OERR Directive 9345.3-02, Management of Investigation-Derived Wastes During Site Inspections.

After sampling, surface soil sample cuttings will be returned to the hole from which they were generated. START-3 anticipates generating minimal amounts of decontamination water since a majority of the sampling equipment used will be disposable. Disposable sampling equipment, acetate liners, and used PPE will be placed in marked 55-gallon drums and disposed of during the removal assessment operation.

3.2.11 Sampling and Sample Handling Procedures

Samples will be collected using equipment and procedures appropriate to the matrix, parameters, and sampling objectives. The volume of the sample collected must be sufficient to perform the analyses requested. Samples must be stored in the proper types of containers and preserved in a manner for the analyses to be performed.

All clean decontaminated sampling equipment and sample containers will be maintained in a clean, segregated area. All samples will be collected with clean decontaminated equipment. All samples collected for laboratory analysis will be placed directly into precleaned, unused glass or plastic containers. Sampling personnel will change gloves between each sample collection/handling. All samples will be assembled and catalogued prior to shipping to the designated laboratory.

Sampling preservation, containers, and hold times for analytical methods associated with this site are presented in Subsection 3.5.

3.2.12 Quality Assurance/Quality Control Samples

START-3 will collect field duplicate and MS/MSD samples of soil and prepare equipment rinsate blank samples as needed during the removal assessment sampling activities. QA/QC samples will be collected according to the following dictates:

- Blind field duplicate soil samples will be collected during sampling activities at locations selected by the START-3 PTL. The data obtained from these samples will be used to assist in the quality assurance of the sampling procedures and laboratory analytical data by allowing an evaluation of reproducibility of results. Efforts will be made to collect duplicate samples in locations where there is visual evidence of contamination or where contamination is suspected. Blind field duplicate samples will be collected at the rate of one duplicate for every 10 samples collected.
- MS/MSD soil samples will be collected during sampling activities at locations selected by the START-3 PTL. The data obtained from these samples will be used to assist in the quality assurance of the sampling procedures and laboratory analytical data by allowing an evaluation of reproducibility of results. Efforts will be made to collect MS/MSD samples in locations where there is visual evidence of contamination or where contamination is suspected. MS/MSD samples will be collected at the rate of one MS/MSD sample for every 20 samples collected.

3.3 SAMPLE MANAGEMENT

Specific nomenclature that will be used by START-3 will provide a consistent means of facilitating the sampling and overall data management for the project as defined in WESTON SOPs. Any deviations from the sample nomenclature proposed below must be approved by the EPA and the project DM.

The nomenclature consists of the following format:

Property ID- Sequential Sample Location - Sample Type+ QC Type - Date

The property ID is a unique identifier used to designate the particular physical location (residence) where the sample was collected. The first two characters identify the city or town. Characters three through six are numeric identifiers. The Sequential Sample Location is sequential number of the sample location at a given property (i.e.; 01 is the first sample location taken at a property; 02 is the second sample location taken at a property). The Station ID and Sequential Sample Location make up the Location for Scribe use.

The Sample Type is a one-digit code used to designate what type of sample was collected as shown below:

1	Background
2	Ludlum "1 minute"
3	Laboratory Radiation "Hot Spot"
4	XRF
5	Indoor Wipe
6	Indoor Radon
7	Open
8	Open
9	Open

The QC Type is a one-digit code used to designate the QC type of the sample as shown below:

1	Normal
2	Duplicate
3	Rinsate Blank
4	Open
5	Open
6	Open

The date must be in the format YYMMDD.

Sequence is an additional parameter used to further differentiate samples (e.g., if two samples were taken from the same sample area on the same day).

Sample data management will be completed utilizing the EPA-provided SCRIBE software provided by EPA.

3.4 DECONTAMINATION

The nondisposable sampling equipment such as soil samplers and hand trowels used during the sample collection process will be thoroughly decontaminated before initial use, between use, and at the end of the field investigation. Equipment decontamination will be completed in the following steps:

- Water spray or brush, if needed, to remove soil/sediment from the equipment.
- Nonphosphate detergent and potable water wash to clean the equipment.
- Final potable water rinse.
- Air-dried equipment.

Personnel decontamination procedures are described in the site-specific HASP. All decontamination activities will be conducted at a temporary decontamination pad that will be constructed in an area to be determined by the PTL prior to the beginning of field activities.

Excess soil and fluids generated as a result of equipment decontamination will be placed in a drum and staged in an area to be determined by the PTL. The drum will be labelled on the side with the name of the site, the contents, sampling location, and date.

3.5 SAMPLE PRESERVATION, CONTAINERS, AND HOLD TIMES

Soil samples will be collected in plastic jars of at least 16-ounce capacity. Once collected, samples will be stored in coolers while at the site and until the samples are submitted for analyses. Samples designated for gamma spectrometry analysis do not require maintenance of a specific temperature range and do not have a holding time limit. Chain-of-custody forms will be completed for each sample shipment and sent with the samples to the designated laboratory by overnight carrier.

Wipe samples will be placed in individual envelopes or plastic bags, sample identification information will be written on them, and the containers will be boxed with completed chain of custody forms for shipment to the laboratory. Samples do not require maintenance of a specific temperature range or compliance with holding times.

It is currently anticipated that START-3 will require a one-month turnaround for gamma spectrometry results without paying premium rates for analyses. This could be revised based on discussions with the EPA OSC. This turnaround time is initiated when the samples are received at the laboratory and continues until the analytical results are made available to START-3 (either verbally or by providing facsimile copies of the results) for review. Samples that have been analyzed will be disposed of by the designated laboratory in accordance with the laboratory SOPs.

4. ANALYTICAL METHODS

START-3 will collect samples for both radiological and chemical analysis.

4.1 RADIOLOGICAL ANALYSIS

Samples collected by START-3 during the removal assessment will by analyzed by a qualified radioanalytical laboratory. The following methods of analyses will be conducted on samples submitted to the laboratory:

Soil

- Gamma spectrometry for soil matrix with focus on uranium and its decay products

Wipe

- Gross alpha counting
- Gamma spectrometry (optional)

Radon

- Gross alpha counting

4.2 CHEMICAL ANALYSIS

Surface soil samples will be analyzed for uranium using a field portable XRF unit. A minimum of ten percent of the samples will be sent to an analytical laboratory for analysis using EPA SW-846 method 6020.

5. DATA VALIDATION

START-3 will validate the radioanalytical data by having each data set reviewed by a professional health physicist. A summary of the data validation and findings will be presented in Summary Reports for each residence as part of the final report. START-3 will evaluate the following to verify that the radioanalytical data are within acceptable QA/QC tolerances:

- The completeness of the Laboratory Reports, verifying that all required components of the report are present and that the samples indicated on the accompanying chain-of-custody are addressed in the report.
- The results of laboratory blank analyses.
- The results of laboratory control sample (LCS) analyses.
- The results of MS/MSD analyses.
- Compound identification and quantification accuracy relative to expected isotopic ratios for uranium and its decay products.
- Laboratory precision, through review of the results for blind field duplicates.

Variances from the QA/QC objectives will be addressed as part of the Data Validation Summary Reports.

6. QUALITY ASSURANCE

Quality assurance will be conducted in accordance with the WESTON Corporate Quality Management Manual, dated March 2004; the WESTON START-3 Quality Management Plan, dated August 2009; and EPA Quality Assurance/Quality Control Guidance for Removal Activities, dated April 1990. Following receipt of the TDD from EPA, a Quality Control (QC) officer will be assigned and will monitor work conducted throughout the entire project including reviewing interim report deliverables and field audits. The START-3 PTL will be responsible for QA/QC of the field investigation activities. The designated laboratory utilized during the investigation will be responsible for QA/QC related to the analytical work. START-3 will also collect samples to verify that laboratory QA/QC is consistent with the required standards and to validate the laboratory data received.

6.1 SAMPLE CUSTODY PROCEDURES

Because of the evidentiary nature of sample collection, the possession of samples must be traceable from the time the samples are collected until they are introduced as evidence in legal proceedings. After sample collection and identification, samples will be maintained under chain-of-custody (COC) procedures. If the sample collected is to be split (laboratory QC), the sample will be allocated into similar sample containers. Sample labels completed with the same information as that on the original sample container will be attached to each of the split samples. All personnel required to package and ship coolers containing potentially hazardous material will be trained accordingly.

START-3 personnel will prepare and complete chain-of-custody forms using the Scribe Environmental Sampling Data Management System (SCRIBE) for all samples sent to a START-3 designated off-site laboratory. The chain-of-custody procedures are documented and will be made available to all personnel involved with the sampling. A typical chain-of-custody record will be completed each time a sample or group of samples is prepared for shipment to the laboratory. The record will repeat the information on each sample label and will serve as documentation of handling during shipment. A copy of this record will remain with the shipped samples at all times, and another copy will be retained by the member of the sampling team who originally relinquished the samples. At the completion of the project, the data manager will export the SCRIBE chain-of-custody documentation to the Analytical Service Tracking System (ANSETS) database.

Samples relinquished to the participating laboratories will be subject to the following procedures for transfer of custody and shipment:

- Samples will be accompanied by the COC record. When transferring possession of samples, the individuals relinquishing and receiving the samples will sign, date, and note the time of the sample transfer on the record. This custody records document transfer of sample custody from the sampler to another person or to the laboratory.

- Samples will be properly packed for shipment and dispatched to the appropriate laboratory for analysis with separate, signed custody records enclosed in each sample box or cooler. Sample shipping containers will be custody-sealed for shipment to the laboratory. The preferred procedure includes use of a custody seal wrapped across filament tape that is wrapped around the package at least twice. The custody seal will then be folded over and stuck to seal to ensure that the only access to the package is by cutting the filament tape or breaking the seal to unwrap the tape.

- If sent by common carrier, a bill of lading or airbill will be used. Bill of lading and airbill receipts will be retained in the project file as part of the permanent documentation of sample shipping and transfer.

SOPs 1101.01 and 1102.01 describe these procedures in more detail.

6.2 PROJECT DOCUMENTATION

All documents will be completed, legibly and in ink and by entry into field logbooks, Response Manager, or SCRIBE. Response Manager is the Enterprise Data Collection System designed to provide near real-time access to non-analytical data normally collected in logbooks. Response Manager provides a standard data collection interface for modules of data normally collected by START-3 field personnel while on-site. These modules fall into two basic categories for Response and Removal. The modules include Emergency Response, Reconnaissance, Facility Assessment, Shipping, Containers, Materials, Calls, HHW, and General/Site Specific data. The system provides users with a standard template for laptop/desktop/tablet PCs that will synchronize to the secure web interface using merge replication technology to provide access to field collected data via on the RRC-EDMS EPA Web Hub. Response Manager also includes a PDA application that provides some of the standard data entry templates from Response Manager to users for field data entry. Response Manager also includes an integrated GPS unit with the secure PDA application, and the coordinates collected in Response Manager are automatically mapped on the RRC-EDMS interactive mapping site. GIS personnel can then access this data to provide comprehensive site maps for decision-making support.

Response Manager also includes an Analytical Module that is designed to give SCRIBE users the ability to synchronize the SCRIBE field data to the RRC-EDMS Web Hub. This allows analytical data managers and data validators access to data to perform reviews from anywhere with an Internet connection. The Analytical Module is designed to take the analytical data entered into EPA SCRIBE software and make it available for multiple users to access on one site. START-3 personnel will utilize SCRIBE for all data entry on-site and will upload to the Response Manager Analytical module.

6.2.1 Field Documentation

The following field documentation will be maintained as described below.

Field Logbook

The field logbook is a descriptive notebook detailing site activities and observations so that an accurate, factual account of field procedures may be reconstructed. All entries will be signed by the individuals making them. Entries should include, at a minimum, the following:

- Site name and project number.
- Names of personnel on-site.
- Dates and times of all entries.
- Description of all site activities, including site entry and exit times.
- Noteworthy events and discussions.
- Weather conditions.
- Site observations.
- Identification and description of samples and locations.
- Subcontractor information and names of on-site personnel.
- Dates and times of sample collections and chain-of-custody information.
- Records of photographs.

- Site sketches.
- Calibration results.

Sample Labels

Sample labels will be securely affixed to the sample container. The labels will clearly identify the particular sample and include the following information:

- Site name and project number.
- Date and time the sample was collected.
- Sample preservation method.
- Analysis requested.
- Sampling location.

Chain-of-Custody Record

A chain-of-custody will be maintained from the time of sample collection until final deposition. Every transfer of custody will be noted and signed for and a copy of the record will be kept by each individual who has signed it. The chain-of-custody is discussed in Subsection 6.1 Sample Custody Procedures.

Custody Seal

Custody seals demonstrate that a sample container has not been tampered with or opened. The individual who has custody of the samples will sign and date the seal and affix it to the container in such a manner that it cannot be opened without breaking the seal.

Photographic Documentation

START-3 will take photographs to document site conditions and activities as site work progresses. Initial conditions should be well documented by photographing features that define the site-related contamination or special working conditions. Representative photographs should be taken of each type of site activity. The photographs should show typical operations and operating conditions as well as special situations and conditions that may arise during site activities. Site final conditions should also be documented as a record of how the site appeared at completion of the work.

All photographs should be taken with either a film camera or digital camera capable of recording the date on the image. Each photograph will be recorded in the logbook and within Response Manager with the location of the photographer, direction the photograph was taken, the subject of the photograph, and its significance (i.e., why the picture was taken). Where appropriate, the photograph location, direction, and subject will also be shown on a site sketch and recorded within Response Manager.

6.2.2 Report Preparation

At the completion of the project, START-3 will review and validate all laboratory data and prepare a draft report of field activities and analytical results for EPA OSC review. Draft deliverable documents will be uploaded to the EPA TeamLink website for EPA OSC review and comment.

6.2.3 Response Manager

START-3 will use Response Manager to collect and organize the data collected from project activities. The information to be included encompasses some or all of the following depending on the specific project needs:

- General Module – Site specific data including location and type of site. It also includes an area for all key site locations including geo-spatial data associated with the key site locations.

- Facility Assessment Module - provides standard templates with the flexibility of adding any additional questions of values to the drop down lists for assessments of structures. Typically utilized for EPA regulated program facilities during an ESF-10 deployment of resources. This module can be utilized to track the assessment of any facilities including multiple assessments of the fixed facilities.

- Properties Module – provides standard templates with the flexibility of adding any additional questions of values to the drop down lists for collection of property data including access agreements and assessments of the property and current status of property with regards to the site removal action.

- Materials Module – provides standard templates for tracking materials that are brought on-site or that are removed from the site.

- Daily Reports – provides standard templates for tracking daily site activities, daily site personnel, and daily site notes for reporting back to the OSC in a POLREP or SITREP.

- Data Files – data files can be uploaded in the photo module section and be associated with individual records or with the site in general. The meta data associated with that data file can be filled in using the photo log fields.

The data stored in the Response Manager database can be viewed and edited by any individual with access rights to those functions. At anytime deemed necessary, POLREP and/or SITREPs can be generated by exporting the data out of Response Manager into Microsoft Excel/Word. The database is stored on a secure server and backed up regularly.

APPENDIX A - SITE-SPECIFIC DATA QUALITY OBJECTIVES

Data Quality Objective 1: Gamma Radiation

<table>
<tr><td colspan="2">STEP 1. STATE THE PROBLEM</td></tr>
<tr><td colspan="2">Homes and related residential structures may have been constructed with or on radioactive uranium mine/mill tailings/waste, and surrounding surface soils may be contaminated with radioactive uranium mine/mill waste. The EPA Region 6 PRB will determine whether the radiological contamination poses an actual or potential imminent and substantial threat to human health and/or the environment.</td></tr>
<tr><td colspan="2">STEP 2. IDENTIFY THE DECISION</td></tr>
<tr><td colspan="2">1. Is the Total Effective Dose Equivalent (TEDE) greater than 15 mRem/yr in the residence/related structure?</td></tr>
<tr><td>IDENTIFY THE ALTERNATIVE ACTIONS THAT MAY BE TAKEN BASED ON THE DECISIONS.</td><td>• If the TEDE is greater than 15 mRem/yr inside the residence, the residents will be relocated and a removal action will be implemented. If the TEDE exceedence is in a related structure only, relocation will be evaluated on a case-by-case basis prior to implementation of the removal action.
• If the yard or compound is contaminated above the DCGL, a removal action will be implemented.
• If the TEDE is less than 15 mrem/yr but some small areas of elevated radioactivity are present, a removal action may be conducted to reduce risk to the residents</td></tr>
<tr><td colspan="2">STEP 3. IDENTIFY INPUTS TO THE DECISION</td></tr>
<tr><td>IDENTIFY THE INFORMATIONAL INPUTS NEEDED TO RESOLVE A DECISION.</td><td>• TEDE (equivalent dose) inside residence.
• Elevated radiological soil contamination in the yard.</td></tr>
<tr><td>IDENTIFY THE SOURCES FOR EACH INFORMATIONAL INPUT AND LIST THE INPUTS THAT ARE OBTAINED THROUGH ENVIRONMENTAL MEASUREMENTS.</td><td>• TEDE (equivalent dose) inside residence calculated from gamma exposure, air and water samples, and radon daughters.
• Gamma survey/soil sampling in the yard.</td></tr>
<tr><td>BASIS FOR THE CONTAMINANT SPECIFIC ACTION LEVELS.</td><td>• The TEDE of 15 mRem/yr is from an increased cancer risk as stated in OSWER 9200-4-18.</td></tr>
<tr><td>IDENTIFY POTENTIAL SAMPLING TECHNIQUES AND APPROPRIATE ANALYTICAL METHODS.</td><td>• TEDE will be calculated using the static dose rate inside the residence and by the activity measured with sodium iodide detectors and pressurized ion chambers. Additional information will be obtained from soil samples and wipe samples.</td></tr>
<tr><td colspan="2">STEP 4. DEFINE THE BOUNDARIES OF THE STUDY</td></tr>
<tr><td>DEFINE THE DOMAIN OR GEOGRAPHIC AREA WITHIN WHICH ALL DECISIONS MUST APPLY.</td><td>Houses and other related residential structures near abandoned Uranium mines and mills in the Ambrosia Lake, and Laguna subdistricts.</td></tr>
<tr><td>SPECIFY THE CHARACTERISTICS THAT DEFINE THE POPULATION OF INTEREST.</td><td>• TEDE calculated from inside of residence/related structure and the surrounding yard.</td></tr>
</table>

DETERMINE WHEN TO COLLECT DATA.	Data will be collected after target residences and related structures have been identified and access has been obtained. Data will apply for each individual residence and related structure tested.
IDENTIFY PRACTICAL CONSTRAINTS ON DATA COLLECTION.	• Access not attainable. • No single instrument can provide qualitative, quantitative, and exposure data for all types of radiation. • The relationship between quantitative and exposure data must be established. • Obstacles in the yards or structures may prevent a thorough radiation survey.
STEP 5. DEVELOP A DECISION RULE	
SPECIFY THE PARAMETERS THAT CHARACTERIZE THE POPULATION OF INTEREST.	The measured readings and samples at each location will be compared to the site-specific action levels.
SPECIFY THE ACTION LEVELS FOR THE DECISION.	• The Action Level for TEDE is 15 mRem/yr inside the residence. • A DCGL will be calculated for each residential area or compound to determine a specific soil action level.
DEVELOP A DECISION RULE.	If the TEDE, exceeds 15 mrem/yr or if the DCGL is exceeded, the structure will be referred to the EPA OSC to determine if additional investigation or a removal action is warranted.
STEP 6. SPECIFY LIMITS ON DECISION ERRORS	
DETERMINE THE POSSIBLE RANGE OF THE PARAMETER OF INTEREST.	Activity and exposure rates can range from background concentrations to more than the DCGLs. Readings are not expected to be greater than 1mR/hr or 1,000,000 counts per minute.
DEFINE BOTH TYPES OF DECISION ERRORS AND IDENTIFY THE POTENTIAL CONSEQUENCES OF EACH.	Type I Error: Deciding that the specified area represented by the field reading or sample does not exceed the site-specific action level when, in truth, the concentration of the contaminant exceeds its site-specific action level. The consequence of this decision error is that contaminated soil or building materials will remain in place, possibly endangering human health and the environment. There may also be potential future liability associated with cleanup costs of leaving contamination in place. This decision error is more severe. Type II Error: Deciding that the specified area represented by the field reading or sample does exceed the site-specific action level when, in truth, it does not. The consequences of this decision error are that remediation of the specified area will continue and unnecessary costs will be incurred.

ESTABLISH THE TRUE STATE OF NATURE FOR EACH DECISION RULE.	The true state of nature when the soil or building materials are decided to be below the site-specific action levels when in fact, they are not below the specified assessment levels, is that the area does need remedial action. The true state of nature when the soil or building materials are decided to be above the site-specific action levels when in fact, they are not above the site specific-action level, is that the area does not need remedial action.
DEFINE THE TRUE STATE OF NATURE FOR THE MORE SEVERE DECISION ERROR AS THE BASELINE CONDITION OR THE NULL HYPOTHESIS (H_o) AND DEFINE THE TRUE STATE FOR THE LESS SEVERE DECISION ERROR AS THE ALTERNATIVE HYPOTHESIS (H_a).	H_o: The material represented by the field reading or sample of the specified area is above the site-specific action level.. H_a: The material represented by the field reading or sample of the specified area is below the site-specific action level.
ASSIGN THE TERMS "FALSE POSITIVE" AND "FALSE NEGATIVE" TO THE PROPER DECISION ERRORS.	• False Positive Error = Type I • False Negative Error = Type II
ASSIGN PROBABILITY VALUES TO POINTS ABOVE AND BELOW THE ACTION LEVEL THAT REFLECT THE ACCEPTABLE PROBABILITY FOR THE OCCURRENCES OF DECISION ERRORS.	To be assigned based on discussions with EPA OSC.
STEP 7. OPTIMIZE THE DESIGN	
REVIEW THE DQOs.	Due to insufficient historical data, determination of the standard deviation was not possible; therefore, sample size calculation using the traditional statistical formula may not be the optimal design. In order to select the optimal sampling program that satisfies the DQOs and is the most resource effective, other elements were considered.
DEVELOP GENERAL SAMPLING AND ANALYSIS DESIGN. • Screening will be conducted in the yards of each residence using 2x2 NaI detectors. • The exterior of each house will be screened with 2x2 NaI detectors. • The walls of each room will be screened with 2x2 NaI detectors. • The dose rate will be measured in each room of the structure using a Pressurized Ion Chamber. • Biased soil samples may be collected from areas in the yard with elevated gamma readings. The soil samples will be analyzed for Radium-226.	

SITE-SPECIFIC DATA QUALITY OBJECTIVES
Data Quality Objective 2: Radon

STEP 1. STATE THE PROBLEM	
Homes and related residential structures may have been constructed with or on radioactive uranium mine/mill tailings/waste, and surrounding surface soils may be contaminated with radioactive uranium mine/mill waste. The EPA Region 6 PRB will determine whether the radiological contamination poses an actual or potential imminent and substantial threat to human health and/or the environment.	
STEP 2. IDENTIFY THE DECISION	
1. Is the Radon level greater than 4 pCi/L inside the residence/related structure?	
IDENTIFY THE ALTERNATIVE ACTIONS THAT MAY BE TAKEN BASED ON THE DECISIONS.	• If the Radon levels are greater than 4 pCi/L inside the residence, the residents will be relocated and a removal action will be implemented. If the Radon exceedence is in a related structure only, relocation will be evaluated on a case-by-case basis prior to implementation of the removal action.
STEP 3. IDENTIFY INPUTS TO THE DECISION	
IDENTIFY THE INFORMATIONAL INPUTS NEEDED TO RESOLVE A DECISION.	• Radon activity inside residence.
IDENTIFY THE SOURCES FOR EACH INFORMATIONAL INPUT AND LIST THE INPUTS THAT ARE OBTAINED THROUGH ENVIRONMENTAL MEASUREMENTS.	• Radon sample collected inside residence.
BASIS FOR THE CONTAMINANT SPECIFIC ACTION LEVELS.	• Action level of 4 pCi/L for Radon activity inside residence is from current EPA policy. •
IDENTIFY POTENTIAL SAMPLING TECHNIQUES AND APPROPRIATE ANALYTICAL METHODS.	• Radon activity inside residence will be measured by collecting samples on charcoal canisters, which will be sent to a laboratory for gross alpha analysis.
STEP 4. DEFINE THE BOUNDARIES OF THE STUDY	
DEFINE THE DOMAIN OR GEOGRAPHIC AREA WITHIN WHICH ALL DECISIONS MUST APPLY.	Houses and other related residential structures near abandoned Uranium mines and mills in the Ambrosia Lake, and Laguna subdistricts.
SPECIFY THE CHARACTERISTICS THAT DEFINE THE POPULATION OF INTEREST.	• Radon activity inside residence/related structure.

DETERMINE WHEN TO COLLECT DATA.	Data will be collected after target residences and related structures have been identified and access has been obtained. Data will apply for each individual residence and related structure tested.
IDENTIFY PRACTICAL CONSTRAINTS ON DATA COLLECTION.	• Access not attainable.
STEP 5. DEVELOP A DECISION RULE	
SPECIFY THE PARAMETERS THAT CHARACTERIZE THE POPULATION OF INTEREST.	The measured readings and samples at each location will be compared to the site-specific action levels.
SPECIFY THE ACTION LEVELS FOR THE DECISION.	• The Action Level for Radon is 4 pCi/L inside the residence.
DEVELOP A DECISION RULE.	If either the Radon action level is exceeded the structure will be referred to the EPA OSC to determine if additional investigation or a removal action is warranted.
STEP 6. SPECIFY LIMITS ON DECISION ERRORS	
DETERMINE THE POSSIBLE RANGE OF THE PARAMETER OF INTEREST.	Radon concentrations can range from 0-10 pCi/L.
DEFINE BOTH TYPES OF DECISION ERRORS AND IDENTIFY THE POTENTIAL CONSEQUENCES OF EACH.	<u>Type I Error</u>: Deciding that the specified area represented by the field reading or sample does not exceed the site-specific action level when, in truth, the concentration of the contaminant exceeds its site-specific action level. The consequence of this decision error is that contaminated soil or building materials will remain in place, possibly endangering human health and the environment. There may also be potential future liability associated with cleanup costs of leaving contamination in place. This decision error is more severe. <u>Type II Error</u>: Deciding that the specified area represented by the field reading or sample does exceed the site-specific action level when, in truth, it does not. The consequences of this decision error are that remediation of the specified area will continue and unnecessary costs will be incurred.
ESTABLISH THE TRUE STATE OF NATURE FOR EACH DECISION RULE.	The true state of nature when the soil or building materials are decided to be below the site-specific action levels when in fact, they are not below the specified assessment levels, is that the area does need remedial action. The true state of nature when the soil or building materials are decided to be above the site-specific action levels when in fact, they are not above the site specific-action level, is that the area does not need remedial action.

DEFINE THE TRUE STATE OF NATURE FOR THE MORE SEVERE DECISION ERROR AS THE BASELINE CONDITION OR THE NULL HYPOTHESIS (H_o) AND DEFINE THE TRUE STATE FOR THE LESS SEVERE DECISION ERROR AS THE ALTERNATIVE HYPOTHESIS (H_a).	H_o: The material represented by the field reading or sample of the specified area is above the site-specific action level.. H_a: The material represented by the field reading or sample of the specified area is below the site-specific action level.
ASSIGN THE TERMS "FALSE POSITIVE" AND "FALSE NEGATIVE" TO THE PROPER DECISION ERRORS.	• False Positive Error = Type I • False Negative Error = Type II
ASSIGN PROBABILITY VALUES TO POINTS ABOVE AND BELOW THE ACTION LEVEL THAT REFLECT THE ACCEPTABLE PROBABILITY FOR THE OCCURRENCES OF DECISION ERRORS.	To be assigned based on discussions with EPA OSC.
STEP 7. OPTIMIZE THE DESIGN	
REVIEW THE DQOs.	Due to insufficient historical data, determination of the standard deviation was not possible; therefore, sample size calculation using the traditional statistical formula may not be the optimal design. In order to select the optimal sampling program that satisfies the DQOs and is the most resource effective, other elements were considered.
DEVELOP GENERAL SAMPLING AND ANALYSIS DESIGN. • A Radon sample will be collected from each house and/or enclosed structure. The sample will be sent to an analytical laboratory for analysis.	

SITE-SPECIFIC DATA QUALITY OBJECTIVES
Data Quality Objective 3: Alpha Radiation

STEP 1. STATE THE PROBLEM	
Homes and related residential structures may have been constructed with or on radioactive uranium mine/mill tailings/waste, and surrounding surface soils may be contaminated with radioactive uranium mine/mill waste. The EPA Region 6 PRB will determine whether the radiological contamination poses an actual or potential imminent and substantial threat to human health and/or the environment.	
STEP 2. IDENTIFY THE DECISION	
1. Is the gross alpha level on the removable contamination on the surface greater than 20 dpm/100 cm^2 inside the residence/related structure?	
IDENTIFY THE ALTERNATIVE ACTIONS THAT MAY BE TAKEN BASED ON THE DECISIONS.	• If the wipe samples indicate elevated levels of removable gross alpha contamination greater than 20 dpm/100 cm^2, a removal action may be implemented to remove loose or localized radiological contamination. Relocation of the residents will be evaluated on a case-by-case basis prior to the implementation of the removal action.
STEP 3. IDENTIFY INPUTS TO THE DECISION	
IDENTIFY THE INFORMATIONAL INPUTS NEEDED TO RESOLVE A DECISION.	• Removable gross alpha contamination inside the residence
IDENTIFY THE SOURCES FOR EACH INFORMATIONAL INPUT AND LIST THE INPUTS THAT ARE OBTAINED THROUGH ENVIRONMENTAL MEASUREMENTS.	• Wipe samples collected inside residence in areas of elevated gamma readings.
BASIS FOR THE CONTAMINANT SPECIFIC ACTION LEVELS.	• Action level of 20 dpm/100 cm^2 for gross alpha inside the residence is from NRC Regulatory Guide 1.86.
IDENTIFY POTENTIAL SAMPLING TECHNIQUES AND APPROPRIATE ANALYTICAL METHODS.	• Removable gross alpha activity will be measured by collecting wipe samples in areas in the house with elevated gamma readings. The wipe samples will be analyzed in the field or will be sent to a laboratory for gross alpha analysis.
STEP 4. DEFINE THE BOUNDARIES OF THE STUDY	
DEFINE THE DOMAIN OR GEOGRAPHIC AREA WITHIN WHICH ALL DECISIONS MUST APPLY.	Houses and other related residential structures near abandoned Uranium mines and mills in the Ambrosia Lake, and Laguna subdistricts.
SPECIFY THE CHARACTERISTICS THAT DEFINE THE POPULATION OF INTEREST.	• Removable gross alpha on the interior surface of the house.

DETERMINE WHEN TO COLLECT DATA.	Data will be collected after target residences and related structures have been identified and access has been obtained. Data will apply for each individual residence and related structure tested.
IDENTIFY PRACTICAL CONSTRAINTS ON DATA COLLECTION.	• Access not attainable.
STEP 5. DEVELOP A DECISION RULE	
SPECIFY THE PARAMETERS THAT CHARACTERIZE THE POPULATION OF INTEREST.	The measured readings and samples at each location will be compared to the site-specific action levels.
SPECIFY THE ACTION LEVELS FOR THE DECISION.	• The Action Level for a wipe sample is 20 alpha radiation disintegrations per minute per 100 square centimeters.
DEVELOP A DECISION RULE.	If the wipe sample action level is exceeded the structure will be referred to the EPA OSC to determine if additional investigation or a removal action is warranted.
STEP 6. SPECIFY LIMITS ON DECISION ERRORS	
DETERMINE THE POSSIBLE RANGE OF THE PARAMETER OF INTEREST.	Alpha activity can range from background concentrations to more than 100 disintegrations per minute per 100 cm^2.
DEFINE BOTH TYPES OF DECISION ERRORS AND IDENTIFY THE POTENTIAL CONSEQUENCES OF EACH.	<u>Type I Error</u>: Deciding that the specified area represented by the field reading or sample does not exceed the site-specific action level when, in truth, the concentration of the contaminant exceeds its site-specific action level. The consequence of this decision error is that contaminated soil or building materials will remain in place, possibly endangering human health and the environment. There may also be potential future liability associated with cleanup costs of leaving contamination in place. This decision error is more severe. <u>Type II Error</u>: Deciding that the specified area represented by the field reading or sample does exceed the site-specific action level when, in truth, it does not. The consequences of this decision error are that remediation of the specified area will continue and unnecessary costs will be incurred.
ESTABLISH THE TRUE STATE OF NATURE FOR EACH DECISION RULE.	The true state of nature when the soil or building materials are decided to be below the site-specific action levels when in fact, they are not below the specified assessment levels, is that the area does need remedial action. The true state of nature when the soil or building materials are decided to be above the site-specific action levels when in fact, they are not above the site specific-action level, is that the area does not need remedial action.

DEFINE THE TRUE STATE OF NATURE FOR THE MORE SEVERE DECISION ERROR AS THE BASELINE CONDITION OR THE NULL HYPOTHESIS (H_o) AND DEFINE THE TRUE STATE FOR THE LESS SEVERE DECISION ERROR AS THE ALTERNATIVE HYPOTHESIS (H_a).	H_o: The material represented by the field reading or sample of the specified area is above the site-specific action level.. H_a: The material represented by the field reading or sample of the specified area is below the site-specific action level.
ASSIGN THE TERMS "FALSE POSITIVE" AND "FALSE NEGATIVE" TO THE PROPER DECISION ERRORS.	• False Positive Error = Type I • False Negative Error = Type II
ASSIGN PROBABILITY VALUES TO POINTS ABOVE AND BELOW THE ACTION LEVEL THAT REFLECT THE ACCEPTABLE PROBABILITY FOR THE OCCURRENCES OF DECISION ERRORS.	To be assigned based on discussions with EPA OSC.
STEP 7. OPTIMIZE THE DESIGN	
REVIEW THE DQOs.	Due to insufficient historical data, determination of the standard deviation was not possible; therefore, sample size calculation using the traditional statistical formula may not be the optimal design. In order to select the optimal sampling program that satisfies the DQOs and is the most resource effective, other elements were considered.
DEVELOP GENERAL SAMPLING AND ANALYSIS DESIGN. • Wipe samples may be collected from areas with elevated gamma readings. The wipe samples will be analyzed for alpha contamination using a portable gross alpha tray counter or sent to an analytical laboratory for gross alpha analysis.	

SITE-SPECIFIC DATA QUALITY OBJECTIVES
Data Quality Objective 4: Total Uranium

STEP 1. STATE THE PROBLEM	
Homes and related residential structures may have been constructed with or on radioactive uranium mine/mill tailings/waste, and surrounding surface soils may be contaminated with radioactive uranium mine/mill waste. The EPA Region 6 PRB will determine whether the radiological contamination poses an actual or potential imminent and substantial threat to human health and/or the environment.	
STEP 2. IDENTIFY THE DECISION	
1. Is the surface soil in the yard or compound contaminated with uranium above the 230 mg/kg screening level?	
IDENTIFY THE ALTERNATIVE ACTIONS THAT MAY BE TAKEN BASED ON THE DECISIONS.	• If the surface soil is contaminated with uranium above the 230 mg/kg screening level, EPA will conduct further investigation into chemical toxicity at the residence.
STEP 3. IDENTIFY INPUTS TO THE DECISION	
IDENTIFY THE INFORMATIONAL INPUTS NEEDED TO RESOLVE A DECISION.	• Elevated uranium concentrations in the soil in the yard.
IDENTIFY THE SOURCES FOR EACH INFORMATIONAL INPUT AND LIST THE INPUTS THAT ARE OBTAINED THROUGH ENVIRONMENTAL MEASUREMENTS.	• Surface soil samples analyzed for uranium
BASIS FOR THE CONTAMINANT SPECIFIC ACTION LEVELS.	• Screening level of 230 mg/kg of uranium is from "Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites".
IDENTIFY POTENTIAL SAMPLING TECHNIQUES AND APPROPRIATE ANALYTICAL METHODS.	• Uranium concentration in soil will be determined by collecting composite surface soil samples. The samples will be screened with an XRF analyzer with laboratory confirmation of at least 10% of the samples.
STEP 4. DEFINE THE BOUNDARIES OF THE STUDY	
DEFINE THE DOMAIN OR GEOGRAPHIC AREA WITHIN WHICH ALL DECISIONS MUST APPLY.	Houses and other related residential structures near abandoned Uranium mines and mills in the Ambrosia Lake, and Laguna subdistricts.
SPECIFY THE CHARACTERISTICS THAT DEFINE THE POPULATION OF INTEREST.	• Uranium concentration in the soils.
DETERMINE WHEN TO COLLECT DATA.	Data will be collected after target residences and related structures have been identified and access has been obtained. Data will apply for each individual residence and related structure tested.
IDENTIFY PRACTICAL CONSTRAINTS ON DATA COLLECTION.	• Access not attainable. • Obstacles in the yards or structures may prevent collecting soil samples in some areas of the yard.

STEP 5. DEVELOP A DECISION RULE	
SPECIFY THE PARAMETERS THAT CHARACTERIZE THE POPULATION OF INTEREST.	The measured readings and samples at each location will be compared to the site-specific action levels.
SPECIFY THE ACTION LEVELS FOR THE DECISION.	• The screening level for uranium in the surface soil is 230 mg/kg.
DEVELOP A DECISION RULE.	If the uranium concentration screening level is exceeded the structure will be referred to the EPA OSC to determine if additional investigation or a removal action is warranted.
STEP 6. SPECIFY LIMITS ON DECISION ERRORS	
DETERMINE THE POSSIBLE RANGE OF THE PARAMETER OF INTEREST.	The concentration of uranium in the soil can range from 0-1,000 mg/kg.
DEFINE BOTH TYPES OF DECISION ERRORS AND IDENTIFY THE POTENTIAL CONSEQUENCES OF EACH.	Type I Error: Deciding that the specified area represented by the field reading or sample does not exceed the site-specific action level when, in truth, the concentration of the contaminant exceeds its site-specific action level. The consequence of this decision error is that contaminated soil or building materials will remain in place, possibly endangering human health and the environment. There may also be potential future liability associated with cleanup costs of leaving contamination in place. This decision error is more severe. Type II Error: Deciding that the specified area represented by the field reading or sample does exceed the site-specific action level when, in truth, it does not. The consequences of this decision error are that remediation of the specified area will continue and unnecessary costs will be incurred.
ESTABLISH THE TRUE STATE OF NATURE FOR EACH DECISION RULE.	The true state of nature when the soil or building materials are decided to be below the site-specific action levels when in fact, they are not below the specified assessment levels, is that the area does need remedial action. The true state of nature when the soil or building materials are decided to be above the site-specific action levels when in fact, they are not above the site specific-action level, is that the area does not need remedial action.
DEFINE THE TRUE STATE OF NATURE FOR THE MORE SEVERE DECISION ERROR AS THE BASELINE CONDITION OR THE NULL HYPOTHESIS (H_o) AND DEFINE THE TRUE STATE FOR THE LESS SEVERE DECISION ERROR AS THE ALTERNATIVE HYPOTHESIS (H_a).	H_o: The material represented by the field reading or sample of the specified area is above the site-specific action level.. H_a: The material represented by the field reading or sample of the specified area is below the site-specific action level.
ASSIGN THE TERMS "FALSE POSITIVE" AND "FALSE NEGATIVE" TO THE PROPER DECISION ERRORS.	• False Positive Error = Type I • False Negative Error = Type II

ASSIGN PROBABILITY VALUES TO POINTS ABOVE AND BELOW THE ACTION LEVEL THAT REFLECT THE ACCEPTABLE PROBABILITY FOR THE OCCURRENCES OF DECISION ERRORS.	To be assigned based on discussions with EPA OSC.
STEP 7. OPTIMIZE THE DESIGN	
REVIEW THE DQOs.	Due to insufficient historical data, determination of the standard deviation was not possible; therefore, sample size calculation using the traditional statistical formula may not be the optimal design. In order to select the optimal sampling program that satisfies the DQOs and is the most resource effective, other elements were considered.
DEVELOP GENERAL SAMPLING AND ANALYSIS DESIGN. • Composite surface soil samples will be collected from the yard. The samples will be screened using a field-portable XRF, with laboratory confirmation on 10% of the samples.	

PROTOCOL
FOR
URANIUM HOME SITE ASSESSMENT
GRANTS MINERAL BELT URANIUM PROJECT
CIBOLA AND McKINLEY COUNTIES, NEW MEXICO

Prepared for

U.S. Environmental Protection Agency Region 6
1445 Ross Ave.
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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHP	Certified Health Physicist
cpm	counts per minute
DCGL	Derived Concentration Guideline Level
DOD	Department of Defense
DOE	Department of Energy
EDE	Effective Dose Equivalent
EPA	U.S. Environmental Protection Agency
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
mrem/y	Millirem per year
μR/h	microRoentgens per hour
NaI	Sodium Iodide
NCRP	National Council on Radiological Protection
NMED	New Mexico Environment Department
NRC	Nuclear Regulatory Commission
OSC	On-Scene Coordinator
pCi/g	Picocuries Per Gram
pCi/L	Picocuries Per Liter
PIC	Pressurized Ionization Chamber
PRG	Preliminary Remediation Goal
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity modeling program
TEDE	Total Effective Dose Equivalent
UHSA	Uranium Home Site Assessment
UMTRCA	Uranium Mill Tailings Radiation Control Act

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) Region 6 Superfund Technical Assessment and Response Team (START-3) contractor, Weston Solutions, Inc. (WESTON®), was tasked by EPA Region 6 Prevention and Response Branch (EPA-PRB) under Contract Number EP-W-06-042, TDD No. TO-0005-09-02-01 to conduct assessments at residences impacted by uranium mining and milling operations in the San Mateo Creek Basin portion of the Grants Mineral Belt, which includes the Ambrosia Lake, Laguna, and Marquez mining sub-districts located in Cibola and McKinley Counties, New Mexico. START-3 was specifically tasked to develop a protocol for the assessment of radioactive contamination at residences using existing radiation guidelines, risk analysis procedures, and exposure models.

The San Mateo Creek Basin portion of the Grants Mineral Belt is located in Cibola and McKinley counties in northwestern New Mexico, near the town of Grants. This area was the site of extensive uranium mining from 1950 until the early 1980s. During this time the economy of the region changed from agriculture to uranium mining and uranium ore processing. Most uranium mining activities stopped in the recession of 1982-1983.

1.1 PROJECT OBJECTIVES

In 2007, EPA Region 9 began a project in coordination with the Navajo Nation to investigate residences on the Navajo Indian Reservation located in parts of Arizona, New Mexico and Utah for radioactive contamination caused by the legacy of uranium mining on the reservation. In 2009, EPA Region 6 initiated a similar project to investigate radioactive contamination in residences near uranium mining and ore processing areas outside of the Navajo Reservation in the San Mateo Creek Basin area of northwestern New Mexico. These areas will include non-Navajo lands adjacent to the eastern boundary of the Navajo Reservation with public and/or private ownership, privately-owned lands, and lands owned by the Laguna and Acoma Pueblos. This document outlines an approach for this investigation, using established EPA guidelines and documents.

The purpose of this document is to develop a survey protocol using the best available science in order to identify residences and related structures where a Removal Action should be performed to eliminate or greatly reduce the threat to the general public health and/or the environment posed by the legacy radiological contamination present on the Site, and to provide sufficient characterization data to allow for planning and cost estimating the removal. The protocol has been designed to maximize the use of field or in-situ data, and to minimize the use of sampling which requires the reliance on laboratory analysis. However, certain determinations such as radon sampling are more efficiently performed with laboratory support; therefore laboratory analysis will be utilized when it is determined to be more advantageous to the project. This document details the development of a protocol for the assessment of radioactive contamination at residences using existing radiation guidelines, risk analysis procedures, and exposure models. Details regarding the assessment procedures including specific instruments, sample analysis, and documentation will be developed and discussed in a separate Quality Assurance Sampling Plan (QASP) document.

2. IDENTIFY GUIDANCE DOCUMENTS

2.1 MARSSIM - PRIMARY GUIDANCE DOCUMENT

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) will be utilized to develop the radiation survey protocol (NRC, 2002). This document was prepared collaboratively by four Federal agencies having authority and control over radioactive materials: Environmental Protection Agency (EPA), Nuclear Regulatory Commission (NRC), Department of Energy (DOE), and Department of Defense (DOD). The MARSSIM, published in 2000, provides a nationally consistent consensus approach to conducting radiation surveys and investigations at potentially contaminated sites. In addition to planning, conducting, and assessing radiological surveys of surface soils and building surfaces, the document provides a decision-making process to determine if site conditions are in compliance with dose-based or risk-based regulatory criteria. As illustrated in Figure 1, the demonstration of compliance with respect to conducting surveys is comprised of three interrelated parts.

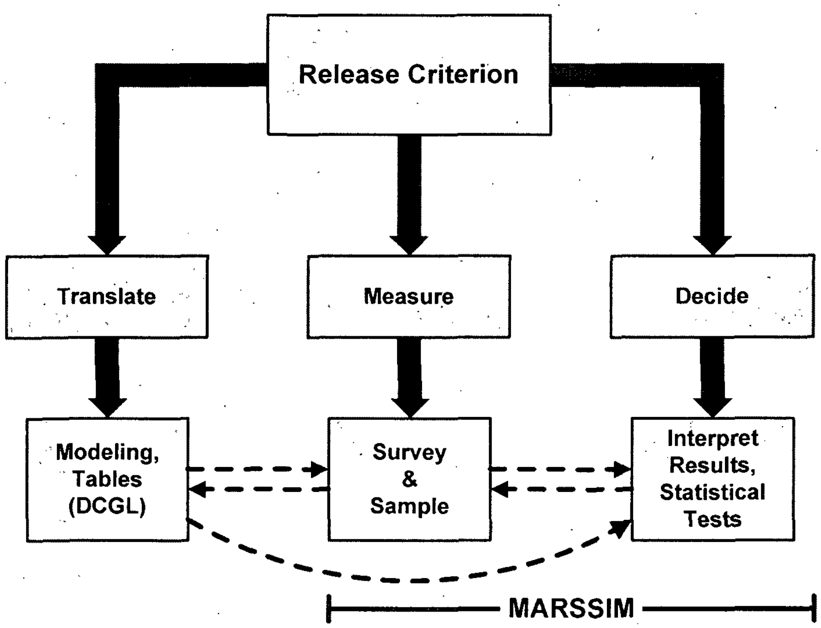

Figure 1
Compliance Demonstration

Translate: Translating the release or cleanup criterion into a corresponding derived concentration guideline level (DCGL) using pathway modeling. This task is not within the scope of MARSSIM.

Measure: Acquiring scientifically defensible site-specific data on the levels and distribution of contamination by employing suitable field or laboratory measurement techniques.

Decide: Determining that the data obtained from sampling does support the assertion that the site meets the release criterion, within an acceptable degree of uncertainty, through application of a statistically based decision rule.

Note that development or calculation of cleanup criterion or DCGLs is not within the scope of MARSSIM. The evaluation of surface water, groundwater, air particulates, radon, radon progeny, or gamma exposure rates is also not within the scope of MARSSIM. The contribution to the overall dose equivalent or risk from these environmental pathways is addressed in the derivation of the DCGLs.

2.2 MARSSIM VERSUS THE CERCLA REMOVAL PROCESS

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Removal Process defined in 40 Code of Federal Regulations (CFR) 300.415 (NCP subpart E-Hazardous substance Response) establishes methods and criteria for determining the extent of response when there is a release into the environment of a hazardous substance or any pollutant that may represent an imminent and substantial danger to the public health or welfare. The survey designs and statistic tests for relatively uniform distributions of radioactivity discussed in MARSSIM are also discussed in CERCLA guidelines. However, MARSSIM includes scanning for radioactive materials, which is not discussed in the more general CERCLA guidelines. MARSSIM is not intended to replace or conflict with existing CERCLA guidelines, but is intended to provide supplemental guidance for specific situations involving radioactive contamination.

The Removal Process is generally composed of four distinct steps: 1) Site referral; 2) Preliminary Removal Assessment; 3) Extent of Contamination; and 4) Removal Action. The scope of this protocol, here in after referred to as the Uranium Home Site Assessment (UHSA) will address the removal process steps 2 and 3, as referenced above. The UHSA protocol has been designed to be conducted in two phases in order to be consistent with EPA removal action policy and general consistency with MARSSIM protocols. The Preliminary Removal Assessment which is equivalent to the MARSSIM Scoping Survey will be conducted on all home site areas within the defined area of interest. If elevated radiological contamination is detected at a home site, the UHSA protocol will transition to the Extent of Contamination, which is the equivalent of a MARSSIM Characterization Survey to define the levels and extent of radiological contamination to allow for planning the Removal Action. Alternatively, if a Removal Action is not warranted, data from the UHSA will be referred to EPA Remedial Program and the New Mexico Environmental Department (NMED) for any further actions deemed necessary.

3. PRELIMINARY REMOVAL ASSESSMENT

The following is a detailed discussion of the science and assumptions made in association with the development of the procedures for the Preliminary Removal Assessment. As previously stated, the UHSA protocol calls for the implementation of these procedures on all home sites within the defined area of interest and is equivalent to the MARSSIM Scoping Survey.

3.1 DEFINE THE RADIOLOGICAL CRITERION

3.1.1 Risk

The Preliminary Remediation Goal (PRG) for Ra-226 is 0.0124 picocuries per gram (pCi/g), which represents a risk of $1x10^{-6}$ (EPA 1997, OSWER 9200.4-18). Since this concentration is below the analytical detection limit of 0.1 pCi/g for this radionuclide, EPA policy states that a $1x10^{-4}$ risk is protective as a removal action objective.

Additionally, according to EPA guidelines, 15 millirem per year (mrem/y) Total Effective Dose Equivalent (TEDE) represents an excess cancer risk of $3x10^{-4}$, and is considered essentially equivalent to the presumptively protective level of $1x10^{-4}$ (EPA 1997, OSWER 9200.4-18). TEDE is the sum of the dose received from external sources and the committed dose from internal exposures. The risk calculation in this case utilizes a 30-year exposure period per lifetime and a 24-hour/day exposure rate. The risk calculation is based upon a risk conversion factor of 7% cancer incidence per 100,000 mrem of TEDE and comes from Biological Effects of Ionizing Radiation Report V (BEIR V 1990). For the purposes of this UHSA protocol, the primary criterion will be a dose of 15 mrem/y (TEDE), which represents a cancer risk of $3x10^{-4}$.

3.1.2 Calculate $DCGL_W$

The DCGL is a radionuclide-specific soil concentration or building surface area concentration that would result in a TEDE equal to the release criterion. Exposure pathway modeling is used to calculate these concentrations. Exposure pathway modeling is the analysis of various exposure pathways and scenarios used to convert concentration into dose. The summation of all doses from all potential pathways is the TEDE.

A number of input variables can significantly affect the calculated result of pathway modeling. These variables include the depth of contamination, residency time, inhalation rates, air particulate re-suspension rates, and percentage of foodstuffs grown locally. Probably the most significant variable impacting the calculation of the DCGL is the modeled area of contamination. Due to the impact that these input parameters have on the results of the program output, they should be selected by a qualified and experienced individual such as a Certified Health Physicist (CHP). If the radioactivity is relatively evenly distributed over a large area, MARSSIM looks at the average concentration over the entire area. This is termed the $DCGL_W$. ($DCGL_W$ stands for DCGL-Wilcoxon, referring to the Wilcoxon statistical test). Concentrations above the $DCGL_W$ are allowed provided that they are of small enough area such that the average concentration over the survey area is still less than the $DCGL_W$. The MARSSIM approach allows for calculation of a higher DCGL Elevated Measurement Comparison ($DCGL_{emc}$) for small areas based upon "area weighting factors." This approach accounts for the fact that the resident will receive a smaller dose from a smaller area of contaminated soil. The $DCGL_{emc}$ is discussed in further detail in Section 3.1.5.

It is important to understand and to restate, $DCGL_w$ and $DCGL_{emc}$ apply only to soil or building surface concentrations. They do not apply to radionuclide concentrations in air particulates, radon, radon progeny, ground water, surface water, food stuffs, or gamma exposure rate. The dose contributions from these potential pathways are calculated from the soil or building surface concentrations by pathway modeling. It is assumed that the radioactive contamination is normally distributed.

This protocol uses RESRAD software to calculate TEDE from soil radionuclide concentrations, although many other programs are available (ANL/EAD, 2001). The RESidaul RADioactivity code was developed by Argonne National Laboratory for the U.S. Department of Energy, and calculates the Effective Dose Equivalent (EDE) from each radionuclide though each pathway. The six pathways evaluated in this protocol development include direct exposure, inhalation of air particulates, and ingestion of plant foods, meat, milk, and soil. Default values are provided for parameters used by the code. Different exposure scenarios can be specified by adding or suppressing pathways and modifying usage or occupancy factors. RESRAD essentially mimics a classic Site Conceptual Model, taking into account all pathways of exposure.

Table 2 summarizes the RESRAD-calculated EDE from all pathways for a UHSA, assuming the standard default values assumed in RESRAD, and assuming an average soil concentration of 1 pCi/g for U-238, U-234, Th-230, Ra-226, Po-210, Pb-210, and all associated progeny in equilibrium. The calculated TEDE to the resident using these assumed input parameters is 17.15 mrem/y. Given that the primary cleanup criterion is 15 mrem/y TEDE, the $DCGL_w$ calculates to approximately 0.9 pCi/g.

Important to note is that the critical radioisotopes to the TEDE in this scenario are Ra-226, contributing approximately 66% of the total dose equivalent, and Pb-210 contributing approximately 31% of the total dose equivalent. All other radioisotopes combined contribute only about 3% to the total dose. Also of note, the critical pathways for these isotopes appear to be the ingestion of plant crops, which contributes approximately 57% of the total dose equivalent, and direct exposure to contaminated ground surface which contributes approximately 37% of the total dose. The other pathways evaluated contribute only approximately 6% to the total dose. A conclusion that can be drawn from this is that the contribution to the total dose from U-238, U-234, and Th-230 is relatively negligible; therefore, the dose impact from either uranium mine waste rock or mill tailings, which have had the uranium extracted, would be substantially equivalent.

As stated previously, changing input parameters can significantly impact the calculated doses. Default values imbedded within RESRAD are generally considered conservative but reasonable input values for the average person within the U.S. However, site-specific parameters can be input into RESRAD which are unique to the local area if these parameters can be identified. A series of RESRAD analyses were performed to identify the more sensitive parameters which affect the calculated result in this scenario. A list of selected input parameters for the generic and site-specific RESRAD analyses is presented as Table 1.

Table 3 provides the calculated EDE from 1 pCi/g of the above radioisotopes assuming the site-specific input variables. The calculated TEDE using these site-specific parameters is 5.9 mrem/y. Given that the primary cleanup criterion is 15 mrem/y TEDE, the $DCGL_W$ calculates to approximately 2.5 pCi/g.

From this data, it can be discerned that the critical radioisotope in the site-specific scenario is Ra-226 which contributes approximately 92% of the TEDE, and the only significant pathway is direct exposure to the soil surface which contributes approximately 92% of the TEDE. To quantify the dose increase due to U-235, which was not considered in the prior RESRAD analyses, the RESRAD calculation was repeated with the uranium-235 chain added. The overall effect was that the TEDE increased from 5.9 to 6.0 mrem. The scenario used was the same in every respect as the one that produced the result presented in Table 3. The marginal dose increase for this scenario further supports the claim that Ra-226 is the critical isotope.

During the assessment work, when a residence is found to have conditions that differ significantly from the assumptions made during the calculation of the $DCGL_W$, the RESRAD model will be run with site-specific parameters to determine a $DCGL_W$ for that residence. In particular, the presence of a vegetable garden in a residential yard could have a large impact on the $DCGL_W$, and the RESRAD model would be run with vegetable consumption information for that particular residence.

A printout of the RESRAD model run using default input parameters is included as Appendix 1. A printout of the RESRAD model run using input parameters specific to the San Mateo Basin is included as Appendix 2.

3.1.3 Identify Critical Pathways

From data in Tables 1 and 2, it is concluded that the critical isotope of concern is Ra-226, and the critical pathway, assuming the site-specific parameters, is the direct exposure to contaminated soil. All other radioisotopes and all other pathways contribute less than 8% to the TEDE. It is also concluded that the $DCGL_W$ for this UHSA will be 2.5 pCi/g of Ra-226 in surface soil. Therefore, Ra-226 is the critical radioisotope that needs to be sampled or measured, and direct exposure is the critical pathway.

3.1.4 Compare DCGLs to Other Published Release Criteria

The $DCGL_W$ can be compared to relevant EPA, NRC, and NCRP criteria for the radioisotope identified as being critical in Section 2.3. These relevant criteria include:

- EPA Site Screening Levels
  - Ra-226 at 0.41 pCi/g above background assuming a risk of $1x10^{-4}$
- EPA Preliminary Remediation Goals (EPA 1997, OSWER 9200.4-18)
  - Ra-226 at 1.2 pCi/g above background for residential soil and 0.06 pCi/g above background for agricultural soil both assuming a $1x10^{-4}$ risk
- EPA UMTRCA standards, 40CFR192
  - Ra-226 in surface soil at 5 pCi/g, above background.
  - Ra-226 in soil below 15 cm at 15 pCi/g above background.
- NRC/NUREG 1757 surface soil screening levels (NRC, 2006)
  - Ra-226 in soil at 0.7 pCi/g above background
- National Council on Radiological Protection (NCRP) Report 129 (NCRP, 1999)
  - Ra-226 in soil in a rural, sparsely vegetated area at 0.1 pCi/g

The State of New Mexico has no regulations that are directly applicable to radioactive contamination in residential soils.

Table 1
Selected Input Parameters for RESRAD Analyses

Parameter	Default Value	Site-Specific Value
Thickness of contaminated soil	2 meters (~ 6 feet)	15 centimeters (~ 6 inches)
Area of yard .	10,000 m^2 (~ 2.5 acres)	4,000 m^2 (~ 1 acre)
Home-grown fruits, vegetables, and grain consumed annually	160 kilograms (~ 350 pounds)	2 kilograms (~4.4 pounds)
Home-grown leafy vegetables consumed annually	14 kilograms (~ 31 pounds)	2 kilograms (~4.4 pounds)

Table 2
Uranium Chain Total Dose from RESRAD Output Using Default Values

Radio-nuclide	Ground		Inhalation		Plant		Meat		Milk		Soil		TEDE[3]
	mrem/yr[1]	fract.[2]	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	
Pb-210	3.445E-03	0.0002	1.189E-03	0.0001	4.769E+00	0.2781	2.670E-01	0.0156	8.798E-02	0.0051	1.725E-01	0.0101	
Po-210	1.345E-05	0.0000	2.744E-04	0.0000	7.556E-02	0.0044	7.766E-02	0.0045	7.530E-03	0.0004	2.373E-02	0.0014	
Ra-226	6.304E+00	0.3676	5.666E-04	0.0000	4.678E+00	0.2728	1.393E-01	0.0081	1.657E-01	0.0097	3.870E-02	0.0023	
Th-230	2.062E-03	0.0001	2.086E-02	0.0012	4.868E-02	0.0028	1.003E-03	0.0001	9.967E-05	0.0000	1.501E-02	0.0009	
U-234	2.320E-04	0.0000	8.433E-03	0.0005	6.149E-02	0.0036	2.029E-03	0.0001	4.974E-03	0.0003	7.734E-03	0.0005	
U-238	8.572E-02	0.0050	7.541E-03	0.0004	5.838E-02	0.0034	1.926E-03	0.0001	4.722E-03	0.0003	7.344E-03	0.0004	
Total	6.395E+00	0.3729	3.887E-02	0.0023	9.691E+00	0.5651	4.890E-01	0.0285	2.710E-01	0.0158	2.650E-01	0.0155	17.15

1 - Maximum dose rate (mrem/yr) occurs at time=0 for a 1000 year assessment.
2 – Fract. = The fraction of the TEDE contributed by a specific radioisotope through a specific pathway.
3 – TEDE = Total Effective Dose Equivalent.

Table 3
Uranium Chain Total Dose from RESRAD Output Using Site-Specific Values

Radio-nuclide	Ground		Inhalation		Plant		Meat		Milk		Soil		TEDE[3]
	mrem/yr[1]	fract.[2]	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	
Pb-210	3.330E-03	0.0006	1.054E-03	0.0002	1.792E-02	0.0030	6.134E-02	0.0104	2.026E-02	0.0034	1.689E-01	0.0285	
Po-210	1.130E-05	0.0000	2.323E-04	0.0000	2.737E-04	0.0000	2.623E-02	0.0044	2.573E-03	0.0004	2.208E-02	0.0037	
Ra-226	5.358E+00	0.9046	5.062E-04	0.0001	1.760E-02	0.0030	1.657E-02	0.0028	2.104E-02	0.0036	3.799E-02	0.0064	
Th-230	1.851E-03	0.0003	1.892E-02	0.0032	1.884E-04	0.0000	3.551E-04	0.0001	2.973E-05	0.0000	1.496E-02	0.0025	
U-234	2.251E-04	0.0000	7.494E-03	0.0013	2.315E-04	0.0000	6.265E-04	0.0001	1.594E-03	0.0003	7.553E-03	0.0013	
U-238	7.693E-02	0.0130	6.702E-03	0.0011	2.198E-04	0.0000	5.949E-04	0.0001	1.514E-03	0.0003	7.172E-03	0.0012	
Total	5.440E+00	0.9185	3.491E-02	0.0059	3.644E-02	0.0062	1.057E-01	0.0178	4.701E-02	0.0079	2.587E-01	0.0437	5.923

1 - Maximum dose rate (mrem/yr) occurs at time=0 for a 1000 year assessment.
2 – Fract. = The fraction of the TEDE contributed by a specific radioisotope through a specific pathway.
3 – TEDE = Total Effective Dose Equivalent.

3.1.5 Calculate $DCGL_{emc}$

As stated previously, the $DCGL_W$ is based on the average soil concentration across the survey unit using exposure pathway models which assume a relatively uniform concentration of contamination. While this represents the ideal situation, small areas of elevated activity are also of concern. Scanning surveys are used to identify these small areas of elevated activity. The criterion to which elevated small areas of contamination are compared is the DCGL Elevated Measurement Comparison, or $DCGL_{emc}$. The $DCGL_{emc}$ is calculated by modifying the $DCGL_W$ using a correction factor that accounts for the difference in area and the resulting change in dose or risk. The area factor is the magnitude by which the concentration within the small area of elevated activity can exceed the $DCGL_W$ while maintaining compliance with the release criterion.

Tables 4 and 5 provide examples of outdoor and indoor area dose factors for Ra-226. If the $DCGL_W$ is multiplied by the appropriate area factor, the resulting concentration distributed over the specified smaller area delivers the same calculated dose. For example, since the $DCGL_W$ for Ra-226 is 2.5 pCi/g (as described in Section 2.2 above) if the elevated concentration detected by scanning has an area of 3 m^2, the $DCGL_{emc}$ would be 2.5 pCi/g times 21.3 or approximately 53 pCi/g.

If multiple elevated areas of contamination are found with multiple radionuclides in addition to a low level of residual radioactivity distributed across the survey unit, the unity rule must be used to ensure that the total dose or risk meets the release criterion.

Table 4
Outdoor Area Dose Factor[1]

Outdoor Area Factor for Radium-226[2]									
Area Size	1m^2	3 m^2	10 m^2	30 m^2	100 m^2	300 m^2	1,000 m^2	3,000 m^2	10,000 m^2
Factor	54.8	21.3	7.8	3.2	1.1	1.1	1.0	1.0	1.0

1 – Taken from MARSSIM, Table 5.6 (NRC, 2002)
2 - The area factor is the magnitude by which the concentration within the small area of elevated activity (hot spot) can exceed the DCGLw while maintaining compliance with the release criterion.

Table 5
Indoor Area Dose Factor[1]

Indoor Area Factor for Radium-226[2]						
Area Size	$1m^2$	$4m^2$	$9m^2$	$16m^2$	$25m^2$	$36m^2$
Factor	18.1	5.5	2.9	1.9	1.3	1.0

1 – Taken from MARSSIM, Table 5.7 (NRC, 2002)
2 - The area factor is the magnitude by which the concentration within the small area of elevated activity (hot spot) can exceed the DCGLw while maintaining compliance with the release criterion.

3.2 DEFINE REFERENCE AREA (BACKGROUND)

Areas which have no reasonable potential for residual contamination are classified as non-impacted areas. A reference area is selected essentially as a background against which readings at residential sites can be compared. The reference area is a non-impacted area representative of the UHSA grouping with similar physical, biological, chemical, and radiological characteristics. Selection is made by gamma radiation level, geological formation, and home-site construction material. Reference area data will be collected for environmental media identified for the critical radioisotopes and critical pathways identified in Section 2.3. For the UHSA protocol, this will require collection of soil samples analyzed for Ra-226, and stationary 1-minute count rate readings above each sample/ measurement location. For sound statistical modeling, a minimum of 20 samples or measurements will be collected for each critical media.

3.3 DEFINE STATISTICAL TEST

Since all of the radioisotopes of concern are also present in the reference area, the Wilcoxon Rank Sum (WRS) test will be used to compare concentrations in background to the concentrations observed on the home site. The WRS test is a two-sample test that compares the distribution of a set of measurements in a survey unit to that of a set of measurements in a reference area. The test is performed by adding the value of the $DCGL_W$ to each measurement in the reference area. The combined set of survey unit data and adjusted reference area data are listed, or ranked, in increasing numerical order. If the ranks of the adjusted reference site measurements are significantly higher than the ranks of the survey unit measurements, the survey unit demonstrates compliance with the release criterion.

3.4 HOME-SITE SCREENING PROTOCOL

This section describes the screening protocol that will be conducted on all home sites within the defined area of interest. The results of this screening will be used to identify which home-sites do not require further action and which home-sites require an extent of contamination survey. The procedures discussed below detail the scanning and stationary readings using gamma sensitive field instruments methodologies for this part of the UHSA.

Scanning is an evaluation technique performed while moving a radiation detector over a surface at a specified speed and distance above the surface. Count rate data is routinely collected at 2 second intervals, numerically converted to counts per minute (cpm), and often tagged with GPS coordinates using a global positioning system. It would be desirable to use gamma scanning data to identify which home sites could be omitted from further consideration. Unfortunately, due to the very low $DCGL_W$, this technique does not appear to have the required sensitivity to make this determination. As an example, MARSSIM table 6.7 (included in this document as Table 7.) provides the scanning sensitivity for Ra-226 using a 2x2 Sodium Iodide (NaI) detector at 2.8 pCi/g, assuming a background count rate of 10,000 cpm. When scanning, MARSSIM recommends a minimum detectable concentration (MDC) of 50% of the $DCGL_W$. Since the $DCGL_W$ for Ra-226 is 2.5 pCi/g above background, the desired sensitivity is 1.25 pCi/g above background. Assuming a background concentration of 1.0 pCi/g, the desired scanning sensitivity is 2.25 pCi/g inclusive of background., which is less than the 2.8 pCi/g sensitivity for this instrument listed in MARSSIM. Gamma scanning will be performed over 100% of the home site outside area to identify localized spots of contamination which are above the $DCGL_W$. Scanning data will be used to estimate the area and Ra-226 concentration in these localized areas of elevated contamination.

Another evaluation technique which is slower, but can achieve lower detection limits, is to collect stationary gamma readings above a fixed point. The count rate collected by this technique can be used to estimate the soil concentration within a reasonable field-of-view of the instrument, based upon both a calculated and an empirically-derived correlation. This technique is not as accurate as actual soil sampling and analysis in a laboratory, but is sufficient to meet the goals of this protocol. Stationary, 1-minute gamma readings will be collected at an 18 inch elevation above the soil surface at defined intervals across the home site. The minimum number of stationary readings will be taken from MARSSIM Table 5.3, plus 20%. MARSSIM Table 5.3 is included in this document as Table 6. The parameters that impact the calculation of the minimum number of measurements are the average concentration of contamination, the variability of the contamination, and the allowable type I and II decision errors. The first two parameters will be based upon scanning survey data, and the type I and II decision errors will be set at 0.05. The minimum number of measurements required to assess a home-site cannot be calculated without site-specific data, but for the typical residence 15 to 20 stationary readings will be sufficient to meet MARSSIM standards.

Stationary in-situ measurements will have a sensitivity of at least 2 pCi/g, inclusive of background for Ra-226, assuming an instrument background of 10,000 cpm. This estimate is calculated by the following analysis. Using Microshield® gamma ray shielding and dose assessment software (Grove, 2008), the exposure rate above an infinite plane of Ra-226 at 2.0 pCi/g was calculated to be 3.9 microRoentgens per hour (μR/h). From table 6.7 in MARSSIM, the response factor for a 2X2 NaI detector exposed to Ra-226 is 760 cpm/μR/h. Therefore, the detector would have a reading of 2934 cpm, above background. The minimum sensitivity of the detector can be calculated from the following formula from MARSSIM section 6.7.1:

$$MDC = (3+4.65(C_b)^{0.5}) / kT$$

Where C_b = background counts, assumed to 10,000 counts in 1 minute

T= background or sample count time, assumed to be 1 minute and

k= units conversion factor, in this situation equal to 1

In this case, the MDC calculates to 468 counts, which is well below the calculated response of 2934 counts resulting from exposure to a Ra-226 concentration of 2 pCi/g.

These calculations should be conducted by a qualified and experienced individual such as a Certified Health Physicist. These calculated results can be verified by empirical measurements described in section 3.5 below.

Table 6
Values of N/2 for Use with the Wilcoxon Rank Sum Test

	α=0.01					α=0.025					α=0.05					α=0.10					α=0.25				
	β					β					β					β					β				
Δ/σ	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25
0.1	5452	4627	3972	3278	2268	4627	3870	3273	2646	1748	3972	3273	2726	2157	1355	3278	2646	2157	1655	964	2268	1748	1355	964	459
0.2	1370	1163	998	824	570	1163	973	823	665	440	998	823	685	542	341	824	665	542	416	243	570	440	341	243	116
0.3	614	521	448	370	256	521	436	369	298	197	448	369	307	243	153	370	298	243	187	109	256	197	153	109	52
0.4	350	350	255	211	146	297	248	210	170	112	255	210	175	139	87	211	170	139	106	62	146	112	87	62	30
0.5	227	193	166	137	95	193	162	137	111	73	166	137	114	90	57	137	111	90	69	41	95	73	57	41	20
0.6	161	137	117	97	67	137	114	97	78	52	117	97	81	64	40	97	78	64	49	29	67	52	40	29	14
0.7	121	103	88	73	51	103	86	73	59	39	88	73	61	48	30	73	59	48	37	22	51	39	30	22	11
0.8	95	81	69	57	40	81	68	57	46	31	69	57	48	38	24	57	46	38	29	17	40	31	24	17	8
0.9	77	66	56	47	32	66	55	46	38	25	56	46	39	31	20	47	38	31	24	14	32	25	20	14	7
1	64	55	47	39	27	55	46	39	32	21	47	39	32	26	16	39	32	26	20	12	27	21	16	12	6
1.1	55	47	40	33	23	47	39	33	27	18	40	33	28	22	14	33	27	22	17	10	23	18	14	10	5
1.2	48	41	35	29	20	41	34	29	24	16	35	29	24	19	12	29	24	19	15	9	20	16	12	9	4
1.3	43	36	31	26	18	36	30	26	21	14	31	26	22	17	11	26	21	17	13	8	18	14	11	8	4
1.4	38	32	28	23	16	32	27	23	19	13	28	23	19	15	10	23	19	15	12	7	16	13	10	7	4
1.5	35	30	25	21	15	30	25	21	17	11	25	21	18	14	9	21	17	14	11	7	15	11	9	7	3
1.6	32	27	23	19	14	27	23	19	16	11	23	19	16	13	8	19	16	13	10	6	14	11	8	6	3
1.7	30	25	22	18	13	25	21	18	15	10	22	18	15	12	8	18	15	12	9	6	13	10	8	6	3
1.8	28	24	20	17	12	24	20	17	14	9	20	17	14	11	7	17	14	11	9	5	12	9	7	5	3
1.9	26	22	19	16	11	22	19	16	13	9	19	16	13	11	7	16	13	11	8	5	11	9	7	5	3
2.0	25	21	18	15	11	21	18	15	12	8	18	15	13	10	7	15	12	10	8	5	11	8	7	5	3
2.25	22	19	16	14	10	19	16	14	11	8	16	14	11	9	6	14	11	9	7	4	10	8	6	4	2
2.5	21	18	15	13	9	18	15	13	10	7	15	13	11	9	6	13	10	9	7	4	9	7	6	4	2
2.75	20	17	15	12	9	17	14	12	10	7	15	12	10	8	5	12	10	8	6	4	9	7	5	4	2
3.0	19	16	14	12	8	16	14	12	10	6	14	12	10	8	5	12	10	8	6	4	8	6	5	4	2
3.5	18	16	13	11	8	16	13	11	9	6	13	11	9	8	5	11	9	8	6	4	8	6	5	4	2
4.0	18	15	13	11	8	15	13	11	9	6	13	11	9	7	5	11	9	7	6	4	8	6	5	4	2

From MARSSIM, Table 5.3

Table 7
NaI Scintillation Detector Scan MDCs for Common Radiological Contaminants

Radionuclide/Radioactive Material	1.25 inch by 1.5 inch NaI Detector		2 inch by 2 inch NaI Detector	
	Scan MDC (Bq/kg)	Weighted cpm/μR/h	Scan MDC (Bq/kg)	Weighted cpm/μR/h
Am-241	1,650	5,830	1,170	13,000
Co-60	215	160	126	430
Cs137	385	350	237	900
Th-230	111,000	43,000	78,400	9,580
Ra-226 (in equilibrium with progeny)	167	300	104	760
Th-232 decay series (Sum of all radionuclides in the thorium decay series)	1,050	340	677	830
Th-232 decay series (In equilibrium with progeny in decay series)	104	340	66.6	830
Depleted Uranium[a] (0.34% U-235)	2,980	1,680	2,070	3,790
Natural Uranium[a]	4,260	1,770	2,960	3,990
3% Enriched Uranium[a]	5,070	2,010	3,540	4,520
20% Enriched Uranium[a]	5,620	2,210	3,960	4,920
50% Enriched Uranium[a]	6,220	2,240	4,370	5,010
75% Enriched Uranium[a]	6,960	2,250	4,880	5,030

[a] Scan MDC for uranium includes sum of U-238, U-235, and U-234

From MARSSIM Table 6.7

3.5 EMPIRICAL MEASUREMENT VERIFICATION

The U.S. Department of Energy (DOE) maintains radiation instrument calibration facilities in Grand Junction, Colorado that will be helpful to demonstrate the sensitivity and validity of the protocol. While these facilities were originally developed to calibrate gamma measuring instruments used in uranium exploration, they are also suitable for calibration of instruments used for remedial action measurements, specifically in-situ assays for natural radionuclides. These facilities were constructed by enriching a concrete mix with uranium ore, monzanite sand, and/or orthoclase sand.

The facilities most applicable to the UHSA protocol are the large area pads, located at the municipal airport in Grand Junction. These concrete pads measure 30 feet by 40 feet by 1.5 feet thick, and are therefore very representative of a uniform plane of contaminated soil. The concentrations of Ra-226, thorium-232 (Th-232), and potassium-40 (K-40) in each of the five calibration pads are provided in the Table 8.

Table 8
Calibration Pad Concentrations

Pad Designation	Concentration (pCi/g)[a]		
	Ra-226	Th-232	K-40
W1	0.82 ± 1.02	0.67 ± 0.10	12.67 ± 0.72
W2	1.92 ± 1.54	0.87 ± 0.12	45.58 ± 1.82
W3	1.70 ± 1.38	4.92 ± 0.26	17.07 ± 0.82
W4	12.07 ± 5.64	1.04 ± 0.12	17.56 ± .098
W5	8.36 ± 3.52	1.91 ± 0.16	34.68 ± 1.46

Note: [a] Uncertainties are 95 percent confidence level.

Empirical verification of the field instruments by using these calibration facilities would enhance the validity of the field measurements in the UHSA.

4. EXTENT OF CONTAMINATION

This section provides a detailed discussion of the science and assumptions made in association with the development of the procedures for the Extent of Contamination survey. The UHSA protocol calls for the implementation of these procedures on all home-sites which have radiological contamination in excess of the acceptable exposure values discussed in Section 3 of this protocol. These procedures are equivalent to the MARSSIM Characterization Survey. The results of this survey will be utilized by the EPA On-Scene Coordinator (OSC) to determine if a removal action on an individual home- site is warranted.

4.1 SOIL SAMPLING

The primary decision method to determine if a home site requires further evaluation will be based on in situ gamma measurements, both scanning and stationary. However, if in-situ gamma measurements indicate that the home site should be further evaluated, soil samples will be collected according to MARSSIM protocol. Since these samples will be collected to define the extent of contamination, the location and number of samples to be collected will be at the discretion of the sampling team, in consultation with the CHP, and under the direction of the EPA OSC. For estimation purposes, it is assumed that approximately 5 soil samples will be collected. Soil samples will be collected from the top 15 centimeters (cm) of soil surface and submitted to a qualified radiochemistry laboratory for gamma spectrometry analysis.

4.2 INDOOR SURVEYS

4.2.1 Gamma Exposure Rate

Based on data presented in Table 2, the dose rate from direct exposure to 2.5 pCi/g of Ra-226 is 13.4 mrem/year, assuming an occupancy factor of 4,380 hours/year indoors and 2,190 hours/year outdoors. Using Microshield® software, the exposure rate at 1 meter above an infinite plane of Ra-226 at 2.5 pCi/g is 4.8 μR/h, or converting to dose rate 3.1 μrem/h. The total dose received outdoors is then 3.1 μrem/h x 2190 hours/year or 6.8 mrem/yr. The remainder of the dose (13.4-6.8), or 6.6 mrem/yr is received indoors over a period of 4380 hours. The indoor dose rate is then 1.6 μrem/h, or converting to exposure rate, 2.5 μR/h. Therefore, if the outside soil is contaminated to a concentration equal to the $DCGL_W$ of 2.5 pCi/g, the allowable exposure rate indoors is 2.5 µR/h.

However, if there is no activity above background outside, all of the dose is received indoors. Using the primary criterion of 15 mrem/year (15,000 µrem/yr), and assuming an indoor residency fraction of 50%, or 4380 hours/year, the average dose rate within any occupied or inhabitable building will be limited to 3.4 µrem/h above background (or converted to exposure rate of 5.3 µR/hour above background). These limits can be compared to the Uranium Mill Tailings Radiation Control Act (UMTRCA) standard of 20 uR/h for indoor spaces. Note, the exposure rate will be the average exposure rate across all livable rooms within the structure, and will be measured using a Pressurized Ionization Chamber (PIC) located in the center of each room. A 2x2 NaI detector will be cross calibrated to the PIC in the home and used to survey for small areas of elevated count rate. The location of any anomalous count rates indicating an exposure rate greater than 2.5 µR/h will be recorded, along with the estimated area of the elevated reading and the maximum exposure rate. If localized areas of elevated gamma exposure are detected, a 100 cm^2 wipe of the area will be collected and the analytical results compared to the 20 dpm/100 cm^2 removable release standard for Ra-226 in NRC Regulatory Guide 1.86.

4.2.2 Indoor Radon Concentration

The criteria to be applied will be the EPA standard of 4 picocuries per Liter (pCi/L). A short-term test of at least 2 days duration will be conducted using either a charcoal canister, alpha track, or other suitable technique to determine the concentration of Rn-222 for that short period. The detector will be placed in the lowest lived-in level of the structure, and the owner will be instructed to keep outside doors and windows closed during the test and for at least 12 hours before initiating the test.

4.3 DATA INTERPRETATION

Data collected from each home-site will be compared to two primary criteria; 1) does the TEDE excluding the contribution from radon progeny, exceed 15 mrem/year, or 2) does the Rn-222 concentration in the dwelling exceed 4 pCi/l. If either criterion is exceeded, the home-site would be considered for a Removal Action.

The radon criterion is the more straightforward to assess. If the Rn-222 concentration exceeds 4 pCi/l, EPA recommends either a second short-term test, or a long-term (90 days) test to verify the measurement. If verification confirms the presence of elevated Rn-222, there are numerous abatement techniques that can be used to reduce the concentration. For example, radon from soil gas is the primary cause of elevated radon. Sealing cracks or gaps in floors, walls, construction joints, and service pipes may reduce the influx of radon into the home. Another source of indoor radon is from well water. Point of treatment can effectively remove radon from the home water supply before it enters the home. A vent pipe system and fan, also known as a soil suction radon reduction system, pulls radon from beneath the structure and vents it to the outside.

Evaluation of site data to the TEDE criterion requires that a qualified health physicist review all of the site data and compare the actual site conditions to the assumptions that were used in developing the $DCGL_W$ using RESRAD. If actual site conditions are materially different than those assumed in RESRAD, a revised $DCGL_W$ will be calculated to which the site will be compared. Assuming actual site conditions are not materially different, the health physicist will estimate the TEDE to the resident based upon the average Ra-226 soil concentration outdoors, the summation of the contribution from localized elevated concentrations (hot spots) of Ra-226 outdoors, the external exposure rate indoors, and any other contributors to the TEDE which are identified during the survey. If the TEDE exceeds 15 mrem/year, the health physicist will meet with the EPA OSC to recommend abatement or mitigating techniques which could reduce the TEDE to an acceptable level. Some examples of techniques that can be used during a removal action include the excavation of localized hot spots of elevated activity in the soil and the removal of contaminated building materials used in the home construction.

Home-sites that have a TEDE above background but below 15 mrem/yr will be referred to the EPA Remedial Program and the NMED for any further actions deemed necessary.

5. REFERENCES

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APPENDIX 1

Printout of the RESRAD Run Using Default Input Parameters

UCHAIN minus GW Rn.TXT

Table of Contents
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Part I: Mixture Sums and Single Radionuclide Guidelines
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Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

0 ³ ³ Current ³ Base ³ Parameter
Menu ³ Parameter ³ Value# ³ Case* ³ Name

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ÄÄÄÄÄÅÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÅÄÄÄÄÄÄÄ
ÄÄÄÄÅÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÅÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
A-1  ³ DCF's for external ground radiation, (mrem/yr)/(pCi/g)    ³           ³           ³
A-1  ³ At-218   (Source: FGR 12)                  ³ 5.847E-03 ³ 5.847E-03 ³ DCF1( 1)
A-1  ³ Bi-210   (Source: FGR 12)                  ³ 3.606E-03 ³ 3.606E-03 ³ DCF1( 2)
A-1  ³ Bi-214   (Source: FGR 12)                  ³ 9.808E+00 ³ 9.808E+00 ³ DCF1( 3)
A-1  ³ Pa-234   (Source: FGR 12)                  ³ 1.155E+01 ³ 1.155E+01 ³ DCF1( 4)
A-1  ³ Pa-234m  (Source: FGR 12)                  ³ 8.967E-02 ³ 8.967E-02 ³ DCF1( 5)
A-1  ³ Pb-210   (Source: FGR 12)                  ³ 2.447E-03 ³ 2.447E-03 ³ DCF1( 6)
A-1  ³ Pb-214   (Source: FGR 12)                  ³ 1.341E+00 ³ 1.341E+00 ³ DCF1( 7)
A-1  ³ Po-210   (Source: FGR 12)                  ³ 5.231E-05 ³ 5.231E-05 ³ DCF1( 8)
A-1  ³ Po-214   (Source: FGR 12)                  ³ 5.138E-04 ³ 5.138E-04 ³ DCF1( 9)
A-1  ³ Po-218   (Source: FGR 12)                  ³ 5.642E-05 ³ 5.642E-05 ³ DCF1( 10)
A-1  ³ Ra-226   (Source: FGR 12)                  ³ 3.176E-02 ³ 3.176E-02 ³ DCF1( 11)
A-1  ³ Rn-222   (Source: FGR 12)                  ³ 2.354E-03 ³ 2.354E-03 ³ DCF1( 12)
A-1  ³ Th-230   (Source: FGR 12)                  ³ 1.209E-03 ³ 1.209E-03 ³ DCF1( 13)
A-1  ³ Th-234   (Source: FGR 12)                  ³ 2.410E-02 ³ 2.410E-02 ³ DCF1( 14)
A-1  ³ Tl-210   (Source: no data)                 ³ 0.000E+00 ³-2.000E+00 ³ DCF1( 15)
A-1  ³ U-234    (Source: FGR 12)                  ³ 4.017E-04 ³ 4.017E-04 ³ DCF1( 16)
A-1  ³ U-238    (Source: FGR 12)                  ³ 1.031E-04 ³ 1.031E-04 ³ DCF1( 17)
     ³                                            ³           ³           ³
B-1  ³ Dose conversion factors for inhalation, mrem/pCi:    ³           ³           ³
B-1  ³ Pb-210+D                                   ³ 1.380E-02 ³ 1.360E-02 ³ DCF2( 1)
B-1  ³ Po-210                                     ³ 9.400E-03 ³ 9.400E-03 ³ DCF2( 2)
B-1  ³ Ra-226+D                                   ³ 8.594E-03 ³ 8.580E-03 ³ DCF2( 3)
B-1  ³ Th-230                                     ³ 3.260E-01 ³ 3.260E-01 ³ DCF2( 4)
B-1  ³ U-234                                      ³ 1.320E-01 ³ 1.320E-01 ³ DCF2( 5)
B-1  ³ U-238                                      ³ 1.180E-01 ³ 1.180E-01 ³ DCF2( 6)
B-1  ³ U-238+D                                    ³ 1.180E-01 ³ 1.180E-01 ³ DCF2( 7)
     ³                                            ³           ³           ³
D-1  ³ Dose conversion factors for ingestion, mrem/pCi:     ³           ³           ³
D-1  ³ Pb-210+D                                   ³ 5.376E-03 ³ 5.370E-03 ³ DCF3( 1)
D-1  ³ Po-210                                     ³ 1.900E-03 ³ 1.900E-03 ³ DCF3( 2)
D-1  ³ Ra-226+D                                   ³ 1.321E-03 ³ 1.320E-03 ³ DCF3( 3)
D-1  ³ Th-230                                     ³ 5.480E-04 ³ 5.480E-04 ³ DCF3( 4)
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D-1  ³ U-234                           ³ 2.830E-04 ³ 2.830E-04 ³ DCF3( 5)
D-1  ³ U-238                           ³ 2.550E-04 ³ 2.550E-04 ³ DCF3( 6)
D-1  ³ U-238+D                         ³ 2.687E-04 ³ 2.550E-04 ³ DCF3( 7)
     ³                                 ³           ³           ³
D-34 ³ Food transfer factors:          ³           ³           ³
D-34 ³ Pb-210+D  , plant/soil concentration ratio, dimensionless   ³ 1.000E-02 ³ 1.000E-02 ³ RTF( 1,1)
D-34 ³ Pb-210+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 8.000E-04 ³ 8.000E-04 ³ RTF( 1,2)
D-34 ³ Pb-210+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 3.000E-04 ³ 3.000E-04 ³ RTF( 1,3)
D-34 ³                                 ³           ³           ³
D-34 ³ Po-210    , plant/soil concentration ratio, dimensionless   ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 2,1)
D-34 ³ Po-210    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 5.000E-03 ³ 5.000E-03 ³ RTF( 2,2)
D-34 ³ Po-210    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 2,3)
D-34 ³                                 ³           ³           ³
D-34 ³ Ra-226+D  , plant/soil concentration ratio, dimensionless   ³ 4.000E-02 ³ 4.000E-02 ³ RTF( 3,1)
D-34 ³ Ra-226+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 3,2)
D-34 ³ Ra-226+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 3,3)
D-34 ³                                 ³           ³           ³
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          Dose Conversion Factor (and Related) Parameter Summary (continued)
                          Dose Library: FGR 11
0     ³                                ³ Current  ³  Base   ³ Parameter
 Menu ³            Parameter           ³  Value#  ³  Case*  ³   Name

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D-34 ³ Th-230    , plant/soil concentration ratio, dimensionless   ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 4,1)
D-34 ³ Th-230    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 1.000E-04 ³ 1.000E-04 ³ RTF( 4,2)
D-34 ³ Th-230    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 5.000E-06 ³ 5.000E-06 ³ RTF( 4,3)
D-34 ³                                 ³           ³           ³
D-34 ³ U-234     , plant/soil concentration ratio, dimensionless   ³ 2.500E-03 ³ 2.500E-03 ³ RTF( 5,1)
D-34 ³ U-234     , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 5,2)
D-34 ³ U-234     , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 6.000E-04 ³ 6.000E-04 ³ RTF( 5,3)
```

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D-34 ³                                                  ³        ³        ³
D-34 ³ U-238     , plant/soil concentration ratio, dimensionless  ³ 2.500E-03 ³ 2.500E-03 ³ RTF( 6,1)
D-34 ³ U-238     , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)  ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 6,2)
D-34 ³ U-238     , milk/livestock-intake ratio, (pCi/L)/(pCi/d)   ³ 6.000E-04 ³ 6.000E-04 ³ RTF( 6,3)
D-34 ³                                                  ³        ³        ³
D-34 ³ U-238+D   , plant/soil concentration ratio, dimensionless  ³ 2.500E-03 ³ 2.500E-03 ³ RTF( 7,1)
D-34 ³ U-238+D   , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)  ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 7,2)
D-34 ³ U-238+D   , milk/livestock-intake ratio, (pCi/L)/(pCi/d)   ³ 6.000E-04 ³ 6.000E-04 ³ RTF( 7,3)
     ³                                                  ³        ³        ³
D-5  ³ Bioaccumulation factors, fresh water, L/kg:      ³        ³        ³
D-5  ³ Pb-210+D  , fish                                 ³ 3.000E+02 ³ 3.000E+02 ³ BIOFAC( 1,1)
D-5  ³ Pb-210+D  , crustacea and mollusks               ³ 1.000E+02 ³ 1.000E+02 ³ BIOFAC( 1,2)
D-5  ³                                                  ³        ³        ³
D-5  ³ Po-210    , fish                                 ³ 1.000E+02 ³ 1.000E+02 ³ BIOFAC( 2,1)
D-5  ³ Po-210    , crustacea and mollusks               ³ 2.000E+04 ³ 2.000E+04 ³ BIOFAC( 2,2)
D-5  ³                                                  ³        ³        ³
D-5  ³ Ra-226+D  , fish                                 ³ 5.000E+01 ³ 5.000E+01 ³ BIOFAC( 3,1)
D-5  ³ Ra-226+D  , crustacea and mollusks               ³ 2.500E+02 ³ 2.500E+02 ³ BIOFAC( 3,2)
D-5  ³                                                  ³        ³        ³
D-5  ³ Th-230    , fish                                 ³ 1.000E+02 ³ 1.000E+02 ³ BIOFAC( 4,1)
D-5  ³ Th-230    , crustacea and mollusks               ³ 5.000E+02 ³ 5.000E+02 ³ BIOFAC( 4,2)
D-5  ³                                                  ³        ³        ³
D-5  ³ U-234     , fish                                 ³ 1.000E+01 ³ 1.000E+01 ³ BIOFAC( 5,1)
D-5  ³ U-234     , crustacea and mollusks               ³ 6.000E+01 ³ 6.000E+01 ³ BIOFAC( 5,2)
D-5  ³                                                  ³        ³        ³
D-5  ³ U-238     , fish                                 ³ 1.000E+01 ³ 1.000E+01 ³ BIOFAC( 6,1)
D-5  ³ U-238     , crustacea and mollusks               ³ 6.000E+01 ³ 6.000E+01 ³ BIOFAC( 6,2)
D-5  ³                                                  ³        ³        ³
D-5  ³ U-238+D   , fish                                 ³ 1.000E+01 ³ 1.000E+01 ³ BIOFAC( 7,1)
D-5  ³ U-238+D   , crustacea and mollusks               ³ 6.000E+01 ³ 6.000E+01 ³ BIOFAC( 7,2)
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#For DCF1(xxx) only, factors are for infinite depth & area.  See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.
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Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	2.000E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Pb-210	1.000E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Po-210	1.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Ra-226	1.000E+00	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Th-230	1.000E+00	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): U-234	1.000E+00	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): U-238	1.000E+00	0.000E+00	---	S1(6)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Po-210	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(6)

³ ³ ³ ³ ³

R013 ³ Cover depth (m) ³ 0.000E+00 ³ 0.000E+00 ³ --- ³ COVER0
R013 ³ Density of cover material (g/cm**3) ³ not used ³ 1.500E+00 ³ --- ³ DENSCV
R013 ³ Cover depth erosion rate (m/yr) ³ not used ³ 1.000E-03 ³ --- ³ VCV
R013 ³ Density of contaminated zone (g/cm**3) ³ 1.500E+00 ³ 1.500E+00 ³ --- ³ DENSCZ
R013 ³ Contaminated zone erosion rate (m/yr) ³ 1.000E-03 ³ 1.000E-03 ³ --- ³ VCZ
R013 ³ Contaminated zone total porosity ³ 4.000E-01 ³ 4.000E-01 ³ --- ³ TPCZ
R013 ³ Contaminated zone field capacity ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ FCCZ
R013 ³ Contaminated zone hydraulic conductivity (m/yr) ³ 1.000E+01 ³ 1.000E+01 ³ --- ³ HCCZ
R013 ³ Contaminated zone b parameter ³ 5.300E+00 ³ 5.300E+00 ³ --- ³ BCZ
R013 ³ Average annual wind speed (m/sec) ³ 2.000E+00 ³ 2.000E+00 ³ --- ³ WIND
R013 ³ Humidity in air (g/m**3) ³ not used ³ 8.000E+00 ³ --- ³ HUMID
R013 ³ Evapotranspiration coefficient ³ 5.000E-01 ³ 5.000E-01 ³ --- ³ EVAPTR
R013 ³ Precipitation (m/yr) ³ 1.000E+00 ³ 1.000E+00 ³ --- ³ PRECIP
R013 ³ Irrigation (m/yr) ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ RI
R013 ³ Irrigation mode ³ overhead ³ overhead ³ --- ³ IDITCH
R013 ³ Runoff coefficient ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ RUNOFF
R013 ³ Watershed area for nearby stream or pond (m**2) ³ 1.000E+06 ³ 1.000E+06 ³ --- ³ WAREA
R013 ³ Accuracy for water/soil computations ³ 1.000E-03 ³ 1.000E-03 ³ --- ³ EPS

³ ³ ³ ³ ³

R014 ³ Density of saturated zone (g/cm**3) ³ 1.500E+00 ³ 1.500E+00 ³ --- ³ DENSAQ
R014 ³ Saturated zone total porosity ³ 4.000E-01 ³ 4.000E-01 ³ --- ³ TPSZ
R014 ³ Saturated zone effective porosity ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ EPSZ

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Site-Specific Parameter Summary (continued)

0 ³ ³ User ³ ³ Used by RESRAD ³ Parameter
Menu ³ Parameter ³ Input ³ Default ³ (If different from user input) ³ Name

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R014 ³ Saturated zone field capacity ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ FCSZ
R014 ³ Saturated zone hydraulic conductivity (m/yr) ³ 1.000E+02 ³ 1.000E+02 ³ --- ³ HCSZ

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R014 ³ Saturated zone hydraulic gradient           ³ 2.000E-02 ³ 2.000E-02 ³     ---        ³ HGWT
R014 ³ Saturated zone b parameter                  ³ 5.300E+00 ³ 5.300E+00 ³     ---        ³ BSZ
R014 ³ Water table drop rate (m/yr)                ³ 1.000E-03 ³ 1.000E-03 ³     ---        ³ VWT
R014 ³ Well pump intake depth (m below water table) ³ 1.000E+01 ³ 1.000E+01 ³    ---        ³ DWIBWT
R014 ³ Model: Nondispersion (ND) or Mass-Balance (MB) ³ ND     ³ ND        ³     ---        ³ MODEL
R014 ³ Well pumping rate (m**3/yr)                 ³ 2.500E+02 ³ 2.500E+02 ³     ---        ³ UW
     ³                                             ³           ³           ³
R015 ³ Number of unsaturated zone strata           ³ 1         ³ 1         ³     ---        ³ NS
R015 ³ Unsat. zone 1, thickness (m)                ³ 4.000E+00 ³ 4.000E+00 ³     ---        ³ H(1)
R015 ³ Unsat. zone 1, soil density (g/cm**3)       ³ 1.500E+00 ³ 1.500E+00 ³     ---        ³ DENSUZ(1)
R015 ³ Unsat. zone 1, total porosity               ³ 4.000E-01 ³ 4.000E-01 ³     ---        ³ TPUZ(1)
R015 ³ Unsat. zone 1, effective porosity           ³ 2.000E-01 ³ 2.000E-01 ³     ---        ³ EPUZ(1)
R015 ³ Unsat. zone 1, field capacity               ³ 2.000E-01 ³ 2.000E-01 ³     ---        ³ FCUZ(1)
R015 ³ Unsat. zone 1, soil-specific b parameter    ³ 5.300E+00 ³ 5.300E+00 ³     ---        ³ BUZ(1)
R015 ³ Unsat. zone 1, hydraulic conductivity (m/yr) ³ 1.000E+01 ³ 1.000E+01 ³    ---        ³ HCUZ(1)
     ³                                             ³           ³           ³
R016 ³ Distribution coefficients for Pb-210        ³           ³           ³                ³
R016 ³   Contaminated zone (cm**3/g)               ³ 1.000E+02 ³ 1.000E+02 ³     ---        ³ DCNUCC( 1)
R016 ³   Unsaturated zone 1 (cm**3/g)              ³ 1.000E+02 ³ 1.000E+02 ³     ---        ³ DCNUCU( 1,1)
R016 ³   Saturated zone (cm**3/g)                  ³ 1.000E+02 ³ 1.000E+02 ³     ---        ³ DCNUCS( 1)
R016 ³   Leach rate (/yr)                          ³ 0.000E+00 ³ 0.000E+00 ³  1.663E-03     ³ ALEACH( 1)
R016 ³   Solubility constant                       ³ 0.000E+00 ³ 0.000E+00 ³  not used      ³ SOLUBK( 1)
     ³                                             ³           ³           ³
R016 ³ Distribution coefficients for Po-210        ³           ³           ³                ³
R016 ³   Contaminated zone (cm**3/g)               ³ 1.000E+01 ³ 1.000E+01 ³     ---        ³ DCNUCC( 2)
R016 ³   Unsaturated zone 1 (cm**3/g)              ³ 1.000E+01 ³ 1.000E+01 ³     ---        ³ DCNUCU( 2,1)
R016 ³   Saturated zone (cm**3/g)                  ³ 1.000E+01 ³ 1.000E+01 ³     ---        ³ DCNUCS( 2)
R016 ³   Leach rate (/yr)                          ³ 0.000E+00 ³ 0.000E+00 ³  1.632E-02     ³ ALEACH( 2)
R016 ³   Solubility constant                       ³ 0.000E+00 ³ 0.000E+00 ³  not used      ³ SOLUBK( 2)
     ³                                             ³           ³           ³
R016 ³ Distribution coefficients for Ra-226        ³           ³           ³                ³
R016 ³   Contaminated zone (cm**3/g)               ³ 7.000E+01 ³ 7.000E+01 ³     ---        ³ DCNUCC( 3)
R016 ³   Unsaturated zone 1 (cm**3/g)              ³ 7.000E+01 ³ 7.000E+01 ³     ---        ³ DCNUCU( 3,1)
R016 ³   Saturated zone (cm**3/g)                  ³ 7.000E+01 ³ 7.000E+01 ³     ---        ³ DCNUCS( 3)
R016 ³   Leach rate (/yr)                          ³ 0.000E+00 ³ 0.000E+00 ³  2.374E-03     ³ ALEACH( 3)
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R016 ³  Solubility constant               ³ 0.000E+00 ³ 0.000E+00 ³     not used       ³ SOLUBK( 3)
   ³                                   ³      ³     ³                 ³
R016 ³ Distribution coefficients for Th-230     ³     ³     ³                 ³
R016 ³  Contaminated zone (cm**3/g)          ³ 6.000E+04 ³ 6.000E+04 ³     ---      ³ DCNUCC( 4)
R016 ³  Unsaturated zone 1 (cm**3/g)         ³ 6.000E+04 ³ 6.000E+04 ³     ---      ³ DCNUCU( 4,1)
R016 ³  Saturated zone (cm**3/g)             ³ 6.000E+04 ³ 6.000E+04 ³     ---      ³ DCNUCS( 4)
R016 ³  Leach rate (/yr)                  ³ 0.000E+00 ³ 0.000E+00 ³     2.778E-06    ³ ALEACH( 4)
R016 ³  Solubility constant               ³ 0.000E+00 ³ 0.000E+00 ³     not used     ³ SOLUBK( 4)
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                    Site-Specific Parameter Summary (continued)
0    ³                          ³  User   ³        ³     Used by RESRAD     ³ Parameter
Menu ³              Parameter           ³  Input  ³ Default ³ (If different from user input) ³   Name

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R016 ³ Distribution coefficients for U-234      ³     ³     ³                 ³
R016 ³  Contaminated zone (cm**3/g)          ³ 5.000E+01 ³ 5.000E+01 ³     ---      ³ DCNUCC( 5)
R016 ³  Unsaturated zone 1 (cm**3/g)         ³ 5.000E+01 ³ 5.000E+01 ³     ---      ³ DCNUCU( 5,1)
R016 ³  Saturated zone (cm**3/g)             ³ 5.000E+01 ³ 5.000E+01 ³     ---      ³ DCNUCS( 5)
R016 ³  Leach rate (/yr)                  ³ 0.000E+00 ³ 0.000E+00 ³     3.319E-03    ³ ALEACH( 5)
R016 ³  Solubility constant               ³ 0.000E+00 ³ 0.000E+00 ³     not used     ³ SOLUBK( 5)
   ³                                   ³      ³     ³                 ³
R016 ³ Distribution coefficients for U-238      ³     ³     ³                 ³
R016 ³  Contaminated zone (cm**3/g)          ³ 5.000E+01 ³ 5.000E+01 ³     ---      ³ DCNUCC( 6)
R016 ³  Unsaturated zone 1 (cm**3/g)         ³ 5.000E+01 ³ 5.000E+01 ³     ---      ³ DCNUCU( 6,1)
R016 ³  Saturated zone (cm**3/g)             ³ 5.000E+01 ³ 5.000E+01 ³     ---      ³ DCNUCS( 6)
R016 ³  Leach rate (/yr)                  ³ 0.000E+00 ³ 0.000E+00 ³     3.319E-03    ³ ALEACH( 6)
R016 ³  Solubility constant               ³ 0.000E+00 ³ 0.000E+00 ³     not used     ³ SOLUBK( 6)
   ³                                   ³      ³     ³                 ³
R017 ³ Inhalation rate (m**3/yr)             ³ 8.400E+03 ³ 8.400E+03 ³     ---      ³ INHALR
R017 ³ Mass loading for inhalation (g/m**3)        ³ 1.000E-04 ³ 1.000E-04 ³     ---      ³ MLINH
R017 ³ Exposure duration                  ³ 3.000E+01 ³ 3.000E+01 ³     ---      ³ ED
```

R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	7.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)

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Summary : Template File for Nuclide Independent Parameters

Site-Specific Parameter Summary (continued)

0 Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	0.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	0.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	5.000E-01	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
R018	Contamination fraction of meat	-1	-1	0.500E+00	FMEAT
R018	Contamination fraction of milk	-1	-1	0.500E+00	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH

```
R019 ³ Livestock water fraction from ground water    ³ 0.000E+00 ³ 1.000E+00 ³         ---        ³ FGWLW
R019 ³ Irrigation fraction from ground water         ³ 0.000E+00 ³ 1.000E+00 ³         ---        ³ FGWIR
   ³                                                 ³           ³           ³                    ³
R19B ³ Wet weight crop yield for Non-Leafy (kg/m**2) ³ 7.000E-01 ³ 7.000E-01 ³         ---        ³ YV(1)
R19B ³ Wet weight crop yield for Leafy     (kg/m**2) ³ 1.500E+00 ³ 1.500E+00 ³         ---        ³ YV(2)
R19B ³ Wet weight crop yield for Fodder    (kg/m**2) ³ 1.100E+00 ³ 1.100E+00 ³         ---        ³ YV(3)
R19B ³ Growing Season for  Non-Leafy (years)         ³ 1.700E-01 ³ 1.700E-01 ³         ---        ³ TE(1)
R19B ³ Growing Season for  Leafy     (years)         ³ 2.500E-01 ³ 2.500E-01 ³         ---        ³ TE(2)
R19B ³ Growing Season for  Fodder    (years)         ³ 8.000E-02 ³ 8.000E-02 ³         ---        ³ TE(3)
R19B ³ Translocation Factor for  Non-Leafy           ³ 1.000E-01 ³ 1.000E-01 ³         ---        ³ TIV(1)
R19B ³ Translocation Factor for  Leafy               ³ 1.000E+00 ³ 1.000E+00 ³         ---        ³ TIV(2)
R19B ³ Translocation Factor for  Fodder              ³ 1.000E+00 ³ 1.000E+00 ³         ---        ³ TIV(3)
R19B ³ Dry Foliar Interception Fraction for  Non-Leafy ³ 2.500E-01 ³ 2.500E-01 ³       ---        ³ RDRY(1)
R19B ³ Dry Foliar Interception Fraction for  Leafy   ³ 2.500E-01 ³ 2.500E-01 ³         ---        ³ RDRY(2)
R19B ³ Dry Foliar Interception Fraction for  Fodder  ³ 2.500E-01 ³ 2.500E-01 ³         ---        ³ RDRY(3)
R19B ³ Wet Foliar Interception Fraction for  Non-Leafy ³ 2.500E-01 ³ 2.500E-01 ³       ---        ³ RWET(1)
R19B ³ Wet Foliar Interception Fraction for  Leafy   ³ 2.500E-01 ³ 2.500E-01 ³         ---        ³ RWET(2)
R19B ³ Wet Foliar Interception Fraction for  Fodder  ³ 2.500E-01 ³ 2.500E-01 ³         ---        ³ RWET(3)
R19B ³ Weathering Removal Constant for Vegetation    ³ 2.000E+01 ³ 2.000E+01 ³         ---        ³ WLAM
   ³                                                 ³           ³           ³                    ³
C14  ³ C-12 concentration in water (g/cm**3)         ³ not used  ³ 2.000E-05 ³         ---        ³ C12WTR
C14  ³ C-12 concentration in contaminated soil (g/g) ³ not used  ³ 3.000E-02 ³         ---        ³ C12CZ
C14  ³ Fraction of vegetation carbon from soil       ³ not used  ³ 2.000E-02 ³         ---        ³ CSOIL
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                          Site-Specific Parameter Summary (continued)
0    ³                                               ³  User     ³           ³     Used by RESRAD     ³ Parameter
Menu ³                 Parameter                     ³  Input    ³  Default  ³ (If different from user input) ³  Name
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C14  ³ Fraction of vegetation carbon from air        ³ not used  ³ 9.800E-01 ³         ---        ³ CAIR
C14  ³ C-14 evasion layer thickness in soil (m)      ³ not used  ³ 3.000E-01 ³         ---        ³ DMC
```


000286

C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

```
TITL ³ Maximum number of integration points for dose  ³  17  ³  ---  ³     ---     ³ LYMAX
TITL ³ Maximum number of integration points for risk  ³   1  ³  ---  ³     ---     ³ KYMAX
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        Summary of Pathway Selections

         Pathway          ³ User Selection
      ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
       1 -- external gamma     ³  active
       2 -- inhalation (w/o radon)³  active
       3 -- plant ingestion    ³  active
       4 -- meat ingestion     ³  active
       5 -- milk ingestion     ³  active
       6 -- aquatic foods      ³  active
       7 -- drinking water     ³  suppressed
       8 -- soil ingestion     ³  active
       9 -- radon              ³  suppressed
       Find peak pathway doses ³  suppressed
      ÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ
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   Contaminated Zone Dimensions     Initial Soil Concentrations, pCi/g
   ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ   ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
    Area:  10000.00 square meters       Pb-210   1.000E+00
  Thickness:    2.00 meters             Po-210   1.000E+00
Cover Depth:    0.00 meters             Ra-226   1.000E+00
                                        Th-230   1.000E+00
```

U-234 1.000E+00
U-238 1.000E+00

0

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

ÄÄÄ

t (years): 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
TDOSE(t): 1.715E+01 1.713E+01 1.706E+01 1.680E+01 1.607E+01 1.370E+01 8.942E+00 6.588E+00
M(t): 6.860E-01 6.853E-01 6.823E-01 6.720E-01 6.426E-01 5.480E-01 3.577E-01 2.635E-01
0Maximum TDOSE(t): 1.715E+01 mrem/yr at t = 0.000E+00 years
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 3.445E-03 0.0002 1.189E-03 0.0001 0.000E+00 0.0000 4.769E+00 0.2781 2.670E-01 0.0156 8.798E-02 0.0051
1.725E-01 0.0101
Po-210 1.345E-05 0.0000 2.744E-04 0.0000 0.000E+00 0.0000 7.556E-02 0.0044 7.766E-02 0.0045 7.530E-03 0.0004 2.373E-02
0.0014
Ra-226 6.304E+00 0.3676 5.666E-04 0.0000 0.000E+00 0.0000 4.678E+00 0.2728 1.393E-01 0.0081 1.657E-01 0.0097
3.870E-02 0.0023
Th-230 2.062E-03 0.0001 2.086E-02 0.0012 0.000E+00 0.0000 4.868E-02 0.0028 1.003E-03 0.0001 9.967E-05 0.0000 1.501E-02
0.0009
U-234 2.320E-04 0.0000 8.433E-03 0.0005 0.000E+00 0.0000 6.149E-02 0.0036 2.029E-03 0.0001 4.974E-03 0.0003 7.734E-03

```
0.0005
 U-238   8.572E-02 0.0050  7.541E-03 0.0004  0.000E+00 0.0000  5.838E-02 0.0034  1.926E-03 0.0001  4.722E-03 0.0003  7.344E-03
0.0004
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 Total   6.395E+00 0.3729  3.887E-02 0.0023  0.000E+00 0.0000  9.691E+00 0.5651  4.890E-01 0.0285  2.710E-01 0.0158  2.650E-01
0.0155
0
               Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                           As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
0                                      Water Dependent Pathways
0           Water          Fish           Radon          Plant          Meat           Milk       All Pathways*
 Radio-  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Nuclide  mrem/yr  fract.  mrem/yr  fract.  mrem/yr  fract.  mrem/yr  fract.  mrem/yr  fract.  mrem/yr  fract.  mrem/yr  fract.
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 Pb-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
5.301E+00 0.3091
 Po-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.848E-01 0.0108
 Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.133E+01 0.6604
 Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
8.772E-02 0.0051
 U-234   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
8.489E-02 0.0049
 U-238   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.656E-01 0.0097
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 Total   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.715E+01 1.0000
0*Sum of all water independent and dependent pathways.
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```

```
                    Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                         As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
0                          Water Independent Pathways (Inhalation excludes radon)
0       Ground       Inhalation       Radon        Plant        Meat         Milk         Soil
 Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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ÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄ
 Pb-210  3.345E-03 0.0002  1.375E-03 0.0001  0.000E+00 0.0000  4.690E+00 0.2738  3.251E-01 0.0190  9.173E-02 0.0054
1.863E-01 0.0109
 Po-210  2.123E-06 0.0000  4.334E-05 0.0000  0.000E+00 0.0000  1.194E-02 0.0007  1.227E-02 0.0007  1.189E-03 0.0001  3.747E-03
0.0002
 Ra-226  6.286E+00 0.3669  6.058E-04 0.0000  0.000E+00 0.0000  4.815E+00 0.2810  1.487E-01 0.0087  1.681E-01 0.0098
4.425E-02 0.0026
 Th-230  4.789E-03 0.0003  2.086E-02 0.0012  0.000E+00 0.0000  5.073E-02 0.0030  1.064E-03 0.0001  1.709E-04 0.0000  1.503E-02
0.0009
 U-234   2.313E-04 0.0000  8.406E-03 0.0005  0.000E+00 0.0000  6.128E-02 0.0036  2.022E-03 0.0001  4.957E-03 0.0003  7.709E-03
0.0004
 U-238   8.544E-02 0.0050  7.516E-03 0.0004  0.000E+00 0.0000  5.819E-02 0.0034  1.920E-03 0.0001  4.707E-03 0.0003  7.319E-03
0.0004
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 Total   6.380E+00 0.3724  3.881E-02 0.0023  0.000E+00 0.0000  9.687E+00 0.5654  4.911E-01 0.0287  2.709E-01 0.0158  2.644E-01
0.0154
0
                    Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                         As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
0                                Water Dependent Pathways
0        Water        Fish         Radon        Plant        Meat         Milk      All Pathways*
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.298E+00 0.3092
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.919E-02 0.0017
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.146E+01 0.6691
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
9.264E-02 0.0054
U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
8.461E-02 0.0049
U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.651E-01 0.0096
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.713E+01 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/06/2009 09:11 Page 13
Summary : Template File for Nuclide Independent Parameters
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 3.135E-03 0.0002 1.328E-03 0.0001 0.000E+00 0.0000 4.404E+00 0.2582 3.158E-01 0.0185 8.701E-02 0.0051
1.780E-01 0.0104
Po-210 5.293E-08 0.0000 1.080E-06 0.0000 0.000E+00 0.0000 2.975E-04 0.0000 3.058E-04 0.0000 2.965E-05 0.0000 9.342E-05
0.0000
Ra-226 6.251E+00 0.3665 6.868E-04 0.0000 0.000E+00 0.0000 5.070E+00 0.2972 1.680E-01 0.0098 1.727E-01 0.0101
5.534E-02 0.0032

000292

Th-230 1.022E-02 0.0006 2.086E-02 0.0012 0.000E+00 0.0000 5.501E-02 0.0032 1.201E-03 0.0001 3.186E-04 0.0000 1.507E-02
0.0009
U-234 2.299E-04 0.0000 8.350E-03 0.0005 0.000E+00 0.0000 6.088E-02 0.0036 2.009E-03 0.0001 4.924E-03 0.0003 7.658E-03
0.0004
U-238 8.488E-02 0.0050 7.467E-03 0.0004 0.000E+00 0.0000 5.780E-02 0.0034 1.907E-03 0.0001 4.676E-03 0.0003 7.271E-03
0.0004
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Total 6.350E+00 0.3722 3.869E-02 0.0023 0.000E+00 0.0000 9.648E+00 0.5656 4.892E-01 0.0287 2.697E-01 0.0158 2.634E-01
0.0154
0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
4.989E+00 0.2925
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
7.276E-04 0.0000
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.172E+01 0.6869
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.027E-01 0.0060
U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
8.405E-02 0.0049
U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.640E-01 0.0096
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.706E+01 1.0000
0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 2.493E-03 0.0001 1.056E-03 0.0001 0.000E+00 0.0000 3.502E+00 0.2085 2.514E-01 0.0150 6.921E-02 0.0041
1.416E-01 0.0084
Po-210 1.295E-13 0.0000 2.643E-12 0.0000 0.000E+00 0.0000 7.278E-10 0.0000 7.481E-10 0.0000 7.252E-11 0.0000 2.285E-10
0.0000
Ra-226 6.130E+00 0.3649 9.292E-04 0.0001 0.000E+00 0.0000 5.819E+00 0.3464 2.255E-01 0.0134 1.861E-01 0.0111
8.854E-02 0.0053
Th-230 2.899E-02 0.0017 2.086E-02 0.0012 0.000E+00 0.0000 7.157E-02 0.0043 1.802E-03 0.0001 8.638E-04 0.0001 1.529E-02
0.0009
U-234 2.258E-04 0.0000 8.160E-03 0.0005 0.000E+00 0.0000 5.948E-02 0.0035 1.963E-03 0.0001 4.811E-03 0.0003 7.483E-03
0.0004
U-238 8.293E-02 0.0049 7.295E-03 0.0004 0.000E+00 0.0000 5.648E-02 0.0034 1.864E-03 0.0001 4.568E-03 0.0003 7.104E-03
0.0004
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Total 6.245E+00 0.3717 3.830E-02 0.0023 0.000E+00 0.0000 9.508E+00 0.5660 4.825E-01 0.0287 2.656E-01 0.0158 2.600E-01
0.0155
0
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Nuclide mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.
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 Pb-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
3.968E+00 0.2362
 Po-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.780E-09 0.0000
 Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.245E+01 0.7411
 Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.394E-01 0.0083
 U-234   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
8.213E-02 0.0049
 U-238   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.602E-01 0.0095
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 Total  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.680E+01 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4      T« Limit = 30 days       05/06/2009  09:11  Page  15
 Summary : Template File for Nuclide Independent Parameters
 File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

                   Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                          As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
0                           Water Independent Pathways (Inhalation excludes radon)
0         Ground        Inhalation        Radon          Plant          Meat          Milk          Soil
 Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Pb-210  1.295E-03 0.0001  5.488E-04 0.0000  0.000E+00 0.0000  1.819E+00 0.1132  1.306E-01 0.0081  3.595E-02 0.0022
7.355E-02 0.0046
 Po-210  1.200E-29 0.0000  2.450E-28 0.0000  0.000E+00 0.0000  6.747E-26 0.0000  6.935E-26 0.0000  6.723E-27 0.0000  2.118E-26
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000295

0.0000
Ra-226 5.797E+00 0.3608 1.346E-03 0.0001 0.000E+00 0.0000 7.050E+00 0.4388 3.244E-01 0.0202 2.066E-01 0.0129
1.463E-01 0.0091
Th-230 8.063E-02 0.0050 2.087E-02 0.0013 0.000E+00 0.0000 1.281E-01 0.0080 4.241E-03 0.0003 2.580E-03 0.0002 1.634E-02
0.0010
U-234 2.210E-04 0.0000 7.639E-03 0.0005 0.000E+00 0.0000 5.568E-02 0.0035 1.837E-03 0.0001 4.502E-03 0.0003 7.005E-03
0.0004
U-238 7.760E-02 0.0048 6.827E-03 0.0004 0.000E+00 0.0000 5.285E-02 0.0033 1.744E-03 0.0001 4.275E-03 0.0003 6.648E-03
0.0004
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Total 5.956E+00 0.3707 3.723E-02 0.0023 0.000E+00 0.0000 9.106E+00 0.5668 4.628E-01 0.0288 2.539E-01 0.0158 2.498E-01
0.0156
0
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.061E+00 0.1283
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.650E-25 0.0000
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.352E+01 0.8419
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.528E-01 0.0157
U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
7.688E-02 0.0048
U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.499E-01 0.0093
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.607E+01 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/06/2009 09:11 Page 16
Summary : Template File for Nuclide Independent Parameters
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 1.308E-04 0.0000 5.545E-05 0.0000 0.000E+00 0.0000 1.838E-01 0.0134 1.319E-02 0.0010 3.633E-03 0.0003 7.431E-03
0.0005
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 4.764E+00 0.3477 1.516E-03 0.0001 0.000E+00 0.0000 7.153E+00 0.5221 3.642E-01 0.0266 1.966E-01 0.0144
1.752E-01 0.0128
Th-230 2.401E-01 0.0175 2.090E-02 0.0015 0.000E+00 0.0000 3.515E-01 0.0257 1.528E-02 0.0011 8.846E-03 0.0006 2.154E-02
0.0016
U-234 2.685E-04 0.0000 6.066E-03 0.0004 0.000E+00 0.0000 4.426E-02 0.0032 1.462E-03 0.0001 3.571E-03 0.0003 5.562E-03
0.0004
U-238 6.151E-02 0.0045 5.413E-03 0.0004 0.000E+00 0.0000 4.190E-02 0.0031 1.383E-03 0.0001 3.390E-03 0.0002 5.271E-03
0.0004
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Total 5.066E+00 0.3697 3.395E-02 0.0025 0.000E+00 0.0000 7.775E+00 0.5675 3.955E-01 0.0289 2.161E-01 0.0158 2.150E-01
0.0157
0
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
0 Water Dependent Pathways

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0        Water       Fish        Radon       Plant       Meat        Milk      All Pathways*
 Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Pb-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
2.083E-01 0.0152
 Po-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
0.000E+00 0.0000
 Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.265E+01 0.9236
 Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
6.582E-01 0.0480
 U-234   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
6.119E-02 0.0045
 U-238   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.189E-01 0.0087
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 Total  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.370E+01 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4     T« Limit = 30 days       05/06/2009  09:11  Page  17
 Summary : Template File for Nuclide Independent Parameters
 File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

           Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                     As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
0                         Water Independent Pathways (Inhalation excludes radon)
0       Ground      Inhalation      Radon       Plant       Meat        Milk        Soil
 Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 1.873E-07 0.0000 7.937E-08 0.0000 0.000E+00 0.0000 2.631E-04 0.0000 1.888E-05 0.0000 5.199E-06 0.0000 1.064E-05 0.0000
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
Ra-226 2.717E+00 0.3039 8.976E-04 0.0001 0.000E+00 0.0000 4.189E+00 0.4685 2.155E-01 0.0241 1.143E-01 0.0128 1.043E-01 0.0117
Th-230 5.550E-01 0.0621 2.095E-02 0.0023 0.000E+00 0.0000 8.345E-01 0.0933 4.009E-02 0.0045 2.204E-02 0.0025 3.350E-02 0.0037
U-234 7.030E-04 0.0001 3.149E-03 0.0004 0.000E+00 0.0000 2.362E-02 0.0026 7.917E-04 0.0001 1.860E-03 0.0002 2.900E-03 0.0003
U-238 3.167E-02 0.0035 2.789E-03 0.0003 0.000E+00 0.0000 2.159E-02 0.0024 7.124E-04 0.0001 1.746E-03 0.0002 2.716E-03 0.0003
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Total 3.305E+00 0.3696 2.779E-02 0.0031 0.000E+00 0.0000 5.069E+00 0.5669 2.571E-01 0.0288 1.400E-01 0.0157 1.435E-01 0.0160
0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 2.981E-04 0.0000
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
Ra-226 0.000E+00 0.0000 3.568E-23 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 7.341E+00 0.8210
Th-230 0.000E+00 0.0000 4.921E-26 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 1.506E+00 0.1684
U-234 0.000E+00 0.0000 9.257E-15 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 3.302E-02 0.0037

U-238 0.000E+00 0.0000 5.492E-20 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
6.122E-02 0.0068
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Total 0.000E+00 0.0000 9.257E-15 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
8.942E+00 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/06/2009 09:11 Page 18
Summary : Template File for Nuclide Independent Parameters
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Pb-210 2.077E-17 0.0000 8.804E-18 0.0000 0.000E+00 0.0000 2.918E-14 0.0000 2.095E-15 0.0000 5.767E-16 0.0000 1.180E-15
0.0000
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 3.809E-01 0.0578 1.258E-04 0.0000 0.000E+00 0.0000 5.872E-01 0.0891 3.022E-02 0.0046 1.602E-02 0.0024 1.463E-02
0.0022
Th-230 9.091E-01 0.1380 2.090E-02 0.0032 0.000E+00 0.0000 1.381E+00 0.2096 6.821E-02 0.0104 3.695E-02 0.0056
4.700E-02 0.0071
U-234 2.130E-03 0.0003 3.590E-04 0.0001 0.000E+00 0.0000 5.435E-03 0.0008 2.313E-04 0.0000 2.653E-04 0.0000 3.922E-04
0.0001
U-238 3.103E-03 0.0005 2.738E-04 0.0000 0.000E+00 0.0000 2.121E-03 0.0003 7.002E-05 0.0000 1.714E-04 0.0000 2.666E-04
0.0000
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Total 1.295E+00 0.1966 2.166E-02 0.0033 0.000E+00 0.0000 1.975E+00 0.2998 9.873E-02 0.0150 5.341E-02 0.0081 6.229E-02
0.0095
0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 6.994E-14 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.030E-13 0.0000
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 0.000E+00 0.0000 2.739E+00 0.4157 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
3.768E+00 0.5719
Th-230 0.000E+00 0.0000 3.363E-01 0.0510 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.799E+00 0.4249
U-234 0.000E+00 0.0000 5.335E-03 0.0008 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.415E-02 0.0021
U-238 0.000E+00 0.0000 9.107E-04 0.0001 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
6.917E-03 0.0010
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Total 0.000E+00 0.0000 3.081E+00 0.4677 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
6.588E+00 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/06/2009 09:11 Page 19
Summary : Template File for Nuclide Independent Parameters
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated
0 Parent Product Thread DSR(j,t) At Time in Years (mrem/yr)/(pCi/g)
(i) (j) Fraction 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
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Pb-210+D	Pb-210+D	1.000E+00	4.986E+00	4.825E+00	4.519E+00	3.593E+00	1.867E+00	1.886E-01	2.700E-04	3.177E-14
Pb-210+D	Po-210	1.000E+00	3.154E-01	4.730E-01	4.699E-01	3.742E-01	1.944E-01	1.964E-02	2.811E-05	7.123E-14
Pb-210+D	äDSR(j)		5.301E+00	5.298E+00	4.989E+00	3.968E+00	2.061E+00	2.083E-01	2.981E-04	1.030E-13
0Po-210	Po-210	1.000E+00	1.848E-01	2.919E-02	7.276E-04	1.780E-09	1.650E-25	0.000E+00	0.000E+00	0.000E+00
0Ra-226+D	Ra-226+D	1.000E+00	1.123E+01	1.120E+01	1.113E+01	1.092E+01	1.032E+01	8.481E+00	4.838E+00	6.855E-01
Ra-226+D	Pb-210+D	1.000E+00	9.292E-02	2.475E-01	5.356E-01	1.395E+00	2.908E+00	3.786E+00	2.271E+00	3.911E-01
Ra-226+D	Po-210	1.000E+00	4.588E-03	1.787E-02	4.744E-02	1.371E-01	2.951E-01	3.878E-01	2.328E-01	2.691E+00
Ra-226+D	äDSR(j)		1.133E+01	1.146E+01	1.172E+01	1.245E+01	1.352E+01	1.265E+01	7.341E+00	3.768E+00
0Th-230	Th-230	1.000E+00	8.534E-02	8.534E-02	8.534E-02	8.533E-02	8.531E-02	8.524E-02	8.504E-02	8.434E-02
Th-230	Ra-226+D	1.000E+00	2.361E-03	7.206E-03	1.688E-02	5.031E-02	1.423E-01	4.262E-01	9.868E-01	1.618E+00
Th-230	Pb-210+D	1.000E+00	1.462E-05	8.912E-05	4.299E-04	3.412E-03	2.288E-02	1.332E-01	3.939E-01	6.991E-01
Th-230	Po-210	1.000E+00	6.061E-07	5.341E-06	3.368E-05	3.192E-04	2.277E-03	1.355E-02	4.028E-02	3.974E-01
Th-230	äDSR(j)		8.772E-02	9.264E-02	1.027E-01	1.394E-01	2.528E-01	6.582E-01	1.506E+00	2.799E+00
0U-234	U-234	1.000E+00	8.489E-02	8.461E-02	8.405E-02	8.212E-02	7.684E-02	6.090E-02	3.134E-02	4.011E-03
U-234	Th-230	1.000E+00	4.048E-07	1.174E-06	2.698E-06	7.951E-06	2.230E-05	6.562E-05	1.457E-04	2.211E-04
U-234	Ra-226+D	1.000E+00	6.945E-09	4.987E-08	2.658E-07	2.360E-06	1.915E-05	1.807E-04	1.097E-03	3.786E-03
U-234	Pb-210+D	1.000E+00	3.497E-11	4.520E-10	4.735E-09	1.111E-07	2.224E-06	4.580E-05	4.040E-04	1.709E-03
U-234	Po-210	1.000E+00	1.272E-12	2.367E-11	3.355E-10	9.942E-09	2.177E-07	4.635E-06	4.125E-05	4.421E-03
U-234	äDSR(j)		8.489E-02	8.461E-02	8.405E-02	8.213E-02	7.688E-02	6.119E-02	3.302E-02	1.415E-02
0U-238	U-238	5.400E-05	4.119E-06	4.106E-06	4.078E-06	3.985E-06	3.729E-06	2.956E-06	1.522E-06	1.953E-07
0U-238+D	U-238+D	9.999E-01	1.656E-01	1.651E-01	1.640E-01	1.602E-01	1.499E-01	1.189E-01	6.119E-02	6.896E-03
U-238+D	U-234	9.999E-01	1.203E-07	3.597E-07	8.338E-07	2.444E-06	6.644E-06	1.735E-05	2.671E-05	1.139E-05
U-238+D	Th-230	9.999E-01	3.955E-13	2.635E-12	1.357E-11	1.181E-10	9.490E-10	8.834E-09	5.197E-08	1.658E-07
U-238+D	Ra-226+D	9.999E-01	4.844E-15	7.498E-14	8.858E-13	2.333E-11	5.462E-10	1.661E-08	2.812E-07	2.439E-06
U-238+D	Pb-210+D	9.999E-01	2.083E-17	5.523E-16	1.234E-14	8.479E-13	4.995E-11	3.550E-09	9.556E-08	1.152E-06
U-238+D	Po-210	9.999E-01	6.805E-19	2.602E-17	8.022E-16	7.276E-14	4.809E-12	3.574E-10	9.741E-09	5.429E-06
U-238+D	äDSR(j)		1.656E-01	1.651E-01	1.640E-01	1.602E-01	1.499E-01	1.189E-01	6.122E-02	6.916E-03

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The DSR includes contributions from associated (half-life ó 30 days) daughters.

1RESRAD, Version 6.4 T« Limit = 30 days 05/06/2009 09:11 Page 20

Summary : Template File for Nuclide Independent Parameters

File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

Single Radionuclide Soil Guidelines G(i,t) in pCi/g

Basic Radiation Dose Limit = 2.500E+01 mrem/yr

```
0Nuclide
 (i)   t= 0.000E+00  1.000E+00  3.000E+00  1.000E+01  3.000E+01  1.000E+02  3.000E+02  1.000E+03
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Pb-210    4.716E+00  4.719E+00  5.011E+00  6.301E+00  1.213E+01  1.200E+02  8.387E+04 *7.634E+13
Po-210    1.353E+02  8.566E+02  3.436E+04  1.405E+10 *4.494E+15 *4.494E+15 *4.494E+15 *4.494E+15
Ra-226    2.207E+00  2.181E+00  2.134E+00  2.008E+00  1.848E+00  1.976E+00  3.405E+00  6.635E+00
Th-230    2.850E+02  2.699E+02  2.435E+02  1.794E+02  9.891E+01  3.798E+01  1.660E+01  8.932E+00
U-234     2.945E+02  2.955E+02  2.974E+02  3.044E+02  3.252E+02  4.086E+02  7.570E+02  1.767E+03
U-238     1.509E+02  1.514E+02  1.524E+02  1.560E+02  1.667E+02  2.103E+02  4.083E+02  3.614E+03
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*At specific activity limit
0
        Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
        and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
      at tmin = time of minimum single radionuclide soil guideline
    and at tmax = time of maximum total dose = 0.000E+00 years
0Nuclide  Initial     tmin      DSR(i,tmin) G(i,tmin) DSR(i,tmax) G(i,tmax)
  (i)   (pCi/g)     (years)              (pCi/g)            (pCi/g)
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Pb-210  1.000E+00    0.000E+00     5.301E+00  4.716E+00  5.301E+00  4.716E+00
Po-210  1.000E+00    0.000E+00     1.848E-01  1.353E+02  1.848E-01  1.353E+02
Ra-226  1.000E+00   45.58 ñ 0.09   1.371E+01  1.824E+00  1.133E+01  2.207E+00
Th-230  1.000E+00    1.000E+03     2.799E+00  8.932E+00  8.772E-02  2.850E+02
U-234   1.000E+00    0.000E+00     8.489E-02  2.945E+02  8.489E-02  2.945E+02
U-238   1.000E+00    0.000E+00     1.656E-01  1.509E+02  1.656E-01  1.509E+02
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1RESRAD, Version 6.4    T« Limit = 30 days     05/06/2009  09:11  Page  21
 Summary : Template File for Nuclide Independent Parameters
 File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

                    Individual Nuclide Dose Summed Over All Pathways
                     Parent Nuclide and Branch Fraction Indicated
0Nuclide Parent   THF(i)                       DOSE(j,t), mrem/yr
```

```
 (j)    (i)          t= 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
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 Pb-210  Pb-210  1.000E+00   4.986E+00 4.825E+00 4.519E+00 3.593E+00 1.867E+00 1.886E-01 2.700E-04 3.177E-14
 Pb-210  Ra-226  1.000E+00   9.292E-02 2.475E-01 5.356E-01 1.395E+00 2.908E+00 3.786E+00 2.271E+00 3.911E-01
 Pb-210  Th-230  1.000E+00   1.462E-05 8.912E-05 4.299E-04 3.412E-03 2.288E-02 1.332E-01 3.939E-01 6.991E-01
 Pb-210  U-234   1.000E+00   3.497E-11 4.520E-10 4.735E-09 1.111E-07 2.224E-06 4.580E-05 4.040E-04 1.709E-03
 Pb-210  U-238   9.999E-01   2.083E-17 5.523E-16 1.234E-14 8.479E-13 4.995E-11 3.550E-09 9.556E-08 1.152E-06
 Pb-210  äDOSE(j)            5.079E+00 5.073E+00 5.055E+00 4.992E+00 4.797E+00 4.107E+00 2.665E+00 1.092E+00
0Po-210  Pb-210  1.000E+00   3.154E-01 4.730E-01 4.699E-01 3.742E-01 1.944E-01 1.964E-02 2.811E-05 7.123E-14
 Po-210  Po-210  1.000E+00   1.848E-01 2.919E-02 7.276E-04 1.780E-09 1.650E-25 0.000E+00 0.000E+00 0.000E+00
 Po-210  Ra-226  1.000E+00   4.588E-03 1.787E-02 4.744E-02 1.371E-01 2.951E-01 3.878E-01 2.328E-01 2.691E+00
 Po-210  Th-230  1.000E+00   6.061E-07 5.341E-06 3.368E-05 3.192E-04 2.277E-03 1.355E-02 4.028E-02 3.974E-01
 Po-210  U-234   1.000E+00   1.272E-12 2.367E-11 3.355E-10 9.942E-09 2.177E-07 4.635E-06 4.125E-05 4.421E-03
 Po-210  U-238   9.999E-01   6.805E-19 2.602E-17 8.022E-16 7.276E-14 4.809E-12 3.574E-10 9.741E-09 5.429E-06
 Po-210  äDOSE(j)            5.047E-01 5.201E-01 5.181E-01 5.116E-01 4.917E-01 4.210E-01 2.732E-01 3.093E+00
0Ra-226  Ra-226  1.000E+00   1.123E+01 1.120E+01 1.113E+01 1.092E+01 1.032E+01 8.481E+00 4.838E+00 6.855E-01
 Ra-226  Th-230  1.000E+00   2.361E-03 7.206E-03 1.688E-02 5.031E-02 1.423E-01 4.262E-01 9.868E-01 1.618E+00
 Ra-226  U-234   1.000E+00   6.945E-09 4.987E-08 2.658E-07 2.360E-06 1.915E-05 1.807E-04 1.097E-03 3.786E-03
 Ra-226  U-238   9.999E-01   4.844E-15 7.498E-14 8.858E-13 2.333E-11 5.462E-10 1.661E-08 2.812E-07 2.439E-06
 Ra-226  äDOSE(j)            1.123E+01 1.120E+01 1.115E+01 1.097E+01 1.046E+01 8.907E+00 5.825E+00 2.307E+00
0Th-230  Th-230  1.000E+00   8.534E-02 8.534E-02 8.534E-02 8.533E-02 8.531E-02 8.524E-02 8.504E-02 8.434E-02
 Th-230  U-234   1.000E+00   4.048E-07 1.174E-06 2.698E-06 7.951E-06 2.230E-05 6.562E-05 1.457E-04 2.211E-04
 Th-230  U-238   9.999E-01   3.955E-13 2.635E-12 1.357E-11 1.181E-10 9.490E-10 8.834E-09 5.197E-08 1.658E-07
 Th-230  äDOSE(j)            8.534E-02 8.534E-02 8.534E-02 8.534E-02 8.534E-02 8.531E-02 8.519E-02 8.457E-02
0U-234   U-234   1.000E+00   8.489E-02 8.461E-02 8.405E-02 8.212E-02 7.684E-02 6.090E-02 3.134E-02 4.011E-03
 U-234   U-238   9.999E-01   1.203E-07 3.597E-07 8.338E-07 2.444E-06 6.644E-06 1.735E-05 2.671E-05 1.139E-05
 U-234   äDOSE(j)            8.489E-02 8.461E-02 8.405E-02 8.212E-02 7.684E-02 6.091E-02 3.136E-02 4.022E-03
0U-238   U-238   5.400E-05   4.119E-06 4.106E-06 4.078E-06 3.985E-06 3.729E-06 2.956E-06 1.522E-06 1.953E-07
 U-238   U-238   9.999E-01   1.656E-01 1.651E-01 1.640E-01 1.602E-01 1.499E-01 1.189E-01 6.119E-02 6.896E-03
 U-238   äDOSE(j)            1.656E-01 1.651E-01 1.640E-01 1.602E-01 1.499E-01 1.189E-01 6.120E-02 6.896E-03
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THF(i) is the thread fraction of the parent nuclide.
1RESRAD, Version 6.4     T« Limit = 30 days       05/06/2009  09:11  Page  22
 Summary : Template File for Nuclide Independent Parameters
```

File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN.RAD

```
                    Individual Nuclide Soil Concentration
                    Parent Nuclide and Branch Fraction Indicated
0Nuclide Parent  THF(i)                 S(j,t), pCi/g
 (j)    (i)       t= 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
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 Pb-210 Pb-210 1.000E+00   1.000E+00 9.678E-01 9.064E-01 7.208E-01 3.744E-01 3.783E-02 5.415E-05 6.006E-15
 Pb-210 Ra-226 1.000E+00   0.000E+00 3.054E-02 8.844E-02 2.612E-01 5.656E-01 7.448E-01 4.472E-01 6.270E-02
 Pb-210 Th-230 1.000E+00   0.000E+00 6.654E-06 5.849E-05 5.996E-04 4.348E-03 2.599E-02 7.733E-02 1.357E-01
 Pb-210 U-234  1.000E+00   0.000E+00 2.001E-11 5.299E-10 1.836E-08 4.137E-07 8.880E-06 7.916E-05 3.129E-04
 Pb-210 U-238  9.999E-01   0.000E+00 1.420E-17 1.131E-15 1.317E-13 9.099E-12 6.838E-10 1.869E-08 1.973E-07
 Pb-210 äS(j):             1.000E+00 9.983E-01 9.949E-01 9.825E-01 9.444E-01 8.087E-01 5.247E-01 1.987E-01
0Po-210 Pb-210 1.000E+00   0.000E+00 8.172E-01 9.107E-01 7.273E-01 3.778E-01 3.818E-02 5.464E-05 6.061E-15
 Po-210 Po-210 1.000E+00   1.000E+00 1.579E-01 3.936E-03 9.628E-09 8.925E-25 0.000E+00 0.000E+00 0.000E+00
 Po-210 Ra-226 1.000E+00   0.000E+00 1.653E-02 7.243E-02 2.470E-01 5.551E-01 7.387E-01 4.439E-01 6.224E-02
 Po-210 Th-230 1.000E+00   0.000E+00 2.715E-06 4.098E-05 5.364E-04 4.179E-03 2.558E-02 7.654E-02 1.345E-01
 Po-210 U-234  1.000E+00   0.000E+00 6.601E-12 3.259E-10 1.561E-08 3.904E-07 8.692E-06 7.823E-05 3.100E-04
 Po-210 U-238  9.999E-01   0.000E+00 3.942E-18 6.214E-16 1.068E-13 8.434E-12 6.656E-10 1.844E-08 1.955E-07
 Po-210 äS(j):             1.000E+00 9.917E-01 9.871E-01 9.748E-01 9.371E-01 8.025E-01 5.206E-01 1.971E-01
0Ra-226 Ra-226 1.000E+00   1.000E+00 9.972E-01 9.916E-01 9.723E-01 9.192E-01 7.553E-01 4.308E-01 6.039E-02
 Ra-226 Th-230 1.000E+00   0.000E+00 4.326E-04 1.294E-03 4.272E-03 1.246E-02 3.775E-02 8.767E-02 1.438E-01
 Ra-226 U-234  1.000E+00   0.000E+00 1.946E-09 1.744E-08 1.910E-07 1.651E-06 1.593E-05 9.733E-05 3.355E-04
 Ra-226 U-238  9.999E-01   0.000E+00 1.838E-15 4.940E-14 1.799E-12 4.635E-11 1.457E-09 2.491E-08 2.154E-07
 Ra-226 äS(j):             1.000E+00 9.976E-01 9.929E-01 9.766E-01 9.317E-01 7.930E-01 5.186E-01 2.045E-01
0Th-230 Th-230 1.000E+00   1.000E+00 1.000E+00 1.000E+00 9.999E-01 9.996E-01 9.988E-01 9.965E-01 9.883E-01
 Th-230 U-234  1.000E+00   0.000E+00 8.987E-06 2.687E-05 8.854E-05 2.570E-04 7.655E-04 1.706E-03 2.589E-03
 Th-230 U-238  9.999E-01   0.000E+00 1.273E-11 1.141E-10 1.248E-09 1.075E-08 1.025E-07 6.075E-07 1.941E-06
 Th-230 äS(j):             1.000E+00 1.000E+00 1.000E+00 1.000E+00 9.999E-01 9.996E-01 9.982E-01 9.909E-01
0U-234  U-234  1.000E+00   1.000E+00 9.967E-01 9.901E-01 9.673E-01 9.051E-01 7.173E-01 3.691E-01 3.608E-02
 U-234  U-238  9.999E-01   0.000E+00 2.825E-06 8.420E-06 2.742E-05 7.698E-05 2.034E-04 3.141E-04 1.024E-04
 U-234  äS(j):             1.000E+00 9.967E-01 9.901E-01 9.674E-01 9.052E-01 7.175E-01 3.695E-01 3.618E-02
0U-238  U-238  5.400E-05   5.400E-05 5.382E-05 5.346E-05 5.224E-05 4.888E-05 3.875E-05 1.995E-05 1.954E-06
 U-238  U-238  9.999E-01   9.999E-01 9.966E-01 9.900E-01 9.673E-01 9.052E-01 7.175E-01 3.694E-01 3.618E-02
```

U-238 äS(j): 1.000E+00 9.967E-01 9.901E-01 9.674E-01 9.052E-01 7.175E-01 3.695E-01 3.618E-02
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THF(i) is the thread fraction of the parent nuclide.

0RESCALC.EXE execution time = 4.69 seconds

APPENDIX 2

Printout of the RESRAD Run Using Site-Specific Input Parameters

1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 1
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Table of Contents
ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
Part I: Mixture Sums and Single Radionuclide Guidelines
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1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 2
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

0 ³ ³ Current ³ Base ³ Parameter
Menu ³ Parameter ³ Value# ³ Case* ³ Name

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A-1  ³ DCF's for external ground radiation, (mrem/yr)/(pCi/g)  ³          ³          ³
A-1  ³ At-218   (Source: FGR 12)              ³ 5.847E-03 ³ 5.847E-03 ³ DCF1( 1)
A-1  ³ Bi-210   (Source: FGR 12)              ³ 3.606E-03 ³ 3.606E-03 ³ DCF1( 2)
A-1  ³ Bi-214   (Source: FGR 12)              ³ 9.808E+00 ³ 9.808E+00 ³ DCF1( 3)
A-1  ³ Pa-234   (Source: FGR 12)              ³ 1.155E+01 ³ 1.155E+01 ³ DCF1( 4)
A-1  ³ Pa-234m  (Source: FGR 12)              ³ 8.967E-02 ³ 8.967E-02 ³ DCF1( 5)
A-1  ³ Pb-210   (Source: FGR 12)              ³ 2.447E-03 ³ 2.447E-03 ³ DCF1( 6)
A-1  ³ Pb-214   (Source: FGR 12)              ³ 1.341E+00 ³ 1.341E+00 ³ DCF1( 7)
A-1  ³ Po-210   (Source: FGR 12)              ³ 5.231E-05 ³ 5.231E-05 ³ DCF1( 8)
A-1  ³ Po-214   (Source: FGR 12)              ³ 5.138E-04 ³ 5.138E-04 ³ DCF1( 9)
A-1  ³ Po-218   (Source: FGR 12)              ³ 5.642E-05 ³ 5.642E-05 ³ DCF1( 10)
A-1  ³ Ra-226   (Source: FGR 12)              ³ 3.176E-02 ³ 3.176E-02 ³ DCF1( 11)
A-1  ³ Rn-222   (Source: FGR 12)              ³ 2.354E-03 ³ 2.354E-03 ³ DCF1( 12)
A-1  ³ Th-230   (Source: FGR 12)              ³ 1.209E-03 ³ 1.209E-03 ³ DCF1( 13)
A-1  ³ Th-234   (Source: FGR 12)              ³ 2.410E-02 ³ 2.410E-02 ³ DCF1( 14)
A-1  ³ Tl-210   (Source: no data)             ³ 0.000E+00 ³-2.000E+00 ³ DCF1( 15)
A-1  ³ U-234    (Source: FGR 12)              ³ 4.017E-04 ³ 4.017E-04 ³ DCF1( 16)
A-1  ³ U-238    (Source: FGR 12)              ³ 1.031E-04 ³ 1.031E-04 ³ DCF1( 17)
     ³                                        ³           ³           ³
B-1  ³ Dose conversion factors for inhalation, mrem/pCi:  ³           ³           ³
B-1  ³ Pb-210+D                               ³ 1.380E-02 ³ 1.360E-02 ³ DCF2( 1)
B-1  ³ Po-210                                 ³ 9.400E-03 ³ 9.400E-03 ³ DCF2( 2)
B-1  ³ Ra-226+D                               ³ 8.594E-03 ³ 8.580E-03 ³ DCF2( 3)
B-1  ³ Th-230                                 ³ 3.260E-01 ³ 3.260E-01 ³ DCF2( 4)
B-1  ³ U-234                                  ³ 1.320E-01 ³ 1.320E-01 ³ DCF2( 5)
B-1  ³ U-238                                  ³ 1.180E-01 ³ 1.180E-01 ³ DCF2( 6)
B-1  ³ U-238+D                                ³ 1.180E-01 ³ 1.180E-01 ³ DCF2( 7)
     ³                                        ³           ³           ³
D-1  ³ Dose conversion factors for ingestion, mrem/pCi:   ³           ³           ³
D-1  ³ Pb-210+D                               ³ 5.376E-03 ³ 5.370E-03 ³ DCF3( 1)
D-1  ³ Po-210                                 ³ 1.900E-03 ³ 1.900E-03 ³ DCF3( 2)
D-1  ³ Ra-226+D                               ³ 1.321E-03 ³ 1.320E-03 ³ DCF3( 3)
D-1  ³ Th-230                                 ³ 5.480E-04 ³ 5.480E-04 ³ DCF3( 4)
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D-1 ³ U-234                                  ³ 2.830E-04 ³ 2.830E-04 ³ DCF3( 5)
D-1 ³ U-238                                  ³ 2.550E-04 ³ 2.550E-04 ³ DCF3( 6)
D-1 ³ U-238+D                                ³ 2.687E-04 ³ 2.550E-04 ³ DCF3( 7)
    ³                                        ³           ³           ³
D-34 ³ Food transfer factors:                ³           ³           ³
D-34 ³ Pb-210+D  , plant/soil concentration ratio, dimensionless   ³ 1.000E-02 ³ 1.000E-02 ³ RTF( 1,1)
D-34 ³ Pb-210+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 8.000E-04 ³ 8.000E-04 ³ RTF( 1,2)
D-34 ³ Pb-210+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 3.000E-04 ³ 3.000E-04 ³ RTF( 1,3)
D-34 ³                                       ³           ³           ³
D-34 ³ Po-210    , plant/soil concentration ratio, dimensionless   ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 2,1)
D-34 ³ Po-210    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 5.000E-03 ³ 5.000E-03 ³ RTF( 2,2)
D-34 ³ Po-210    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 2,3)
D-34 ³                                       ³           ³           ³
D-34 ³ Ra-226+D  , plant/soil concentration ratio, dimensionless   ³ 4.000E-02 ³ 4.000E-02 ³ RTF( 3,1)
D-34 ³ Ra-226+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 3,2)
D-34 ³ Ra-226+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 3,3)
D-34 ³                                       ³           ³           ³
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 Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
 File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

          Dose Conversion Factor (and Related) Parameter Summary (continued)
                              Dose Library: FGR 11
0    ³                                       ³ Current ³  Base   ³ Parameter
 Menu ³              Parameter               ³ Value#  ³ Case*   ³   Name

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D-34 ³ Th-230    , plant/soil concentration ratio, dimensionless   ³ 1.000E-03 ³ 1.000E-03 ³ RTF( 4,1)
D-34 ³ Th-230    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 1.000E-04 ³ 1.000E-04 ³ RTF( 4,2)
D-34 ³ Th-230    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 5.000E-06 ³ 5.000E-06 ³ RTF( 4,3)
D-34 ³                                       ³           ³           ³
D-34 ³ U-234     , plant/soil concentration ratio, dimensionless   ³ 2.500E-03 ³ 2.500E-03 ³ RTF( 5,1)
D-34 ³ U-234     , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)   ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 5,2)
D-34 ³ U-234     , milk/livestock-intake ratio, (pCi/L)/(pCi/d)    ³ 6.000E-04 ³ 6.000E-04 ³ RTF( 5,3)
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D-34 ³                                                   ³      ³      ³
D-34 ³ U-238    , plant/soil concentration ratio, dimensionless  ³ 2.500E-03 ³ 2.500E-03 ³ RTF( 6,1)
D-34 ³ U-238    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)  ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 6,2)
D-34 ³ U-238    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)   ³ 6.000E-04 ³ 6.000E-04 ³ RTF( 6,3)
D-34 ³                                                   ³      ³      ³
D-34 ³ U-238+D  , plant/soil concentration ratio, dimensionless  ³ 2.500E-03 ³ 2.500E-03 ³ RTF( 7,1)
D-34 ³ U-238+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)  ³ 3.400E-04 ³ 3.400E-04 ³ RTF( 7,2)
D-34 ³ U-238+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)   ³ 6.000E-04 ³ 6.000E-04 ³ RTF( 7,3)
     ³                                                   ³      ³      ³
D-5  ³ Bioaccumulation factors, fresh water, L/kg:       ³      ³      ³
D-5  ³ Pb-210+D , fish                      ³ 3.000E+02 ³ 3.000E+02 ³ BIOFAC( 1,1)
D-5  ³ Pb-210+D , crustacea and mollusks    ³ 1.000E+02 ³ 1.000E+02 ³ BIOFAC( 1,2)
D-5  ³                                      ³      ³      ³
D-5  ³ Po-210   , fish                      ³ 1.000E+02 ³ 1.000E+02 ³ BIOFAC( 2,1)
D-5  ³ Po-210   , crustacea and mollusks    ³ 2.000E+04 ³ 2.000E+04 ³ BIOFAC( 2,2)
D-5  ³                                      ³      ³      ³
D-5  ³ Ra-226+D , fish                      ³ 5.000E+01 ³ 5.000E+01 ³ BIOFAC( 3,1)
D-5  ³ Ra-226+D , crustacea and mollusks    ³ 2.500E+02 ³ 2.500E+02 ³ BIOFAC( 3,2)
D-5  ³                                      ³      ³      ³
D-5  ³ Th-230   , fish                      ³ 1.000E+02 ³ 1.000E+02 ³ BIOFAC( 4,1)
D-5  ³ Th-230   , crustacea and mollusks    ³ 5.000E+02 ³ 5.000E+02 ³ BIOFAC( 4,2)
D-5  ³                                      ³      ³      ³
D-5  ³ U-234    , fish                      ³ 1.000E+01 ³ 1.000E+01 ³ BIOFAC( 5,1)
D-5  ³ U-234    , crustacea and mollusks    ³ 6.000E+01 ³ 6.000E+01 ³ BIOFAC( 5,2)
D-5  ³                                      ³      ³      ³
D-5  ³ U-238    , fish                      ³ 1.000E+01 ³ 1.000E+01 ³ BIOFAC( 6,1)
D-5  ³ U-238    , crustacea and mollusks    ³ 6.000E+01 ³ 6.000E+01 ³ BIOFAC( 6,2)
D-5  ³                                      ³      ³      ³
D-5  ³ U-238+D  , fish                      ³ 1.000E+01 ³ 1.000E+01 ³ BIOFAC( 7,1)
D-5  ³ U-238+D  , crustacea and mollusks    ³ 6.000E+01 ³ 6.000E+01 ³ BIOFAC( 7,2)
ÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ
#For DCF1(xxx) only, factors are for infinite depth & area.  See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.
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Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
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Site-Specific Parameter Summary

0 ³ ³ User ³ ³ Used by RESRAD ³ Parameter
Menu ³ Parameter ³ Input ³ Default ³ (If different from user input) ³ Name

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R011 ³ Area of contaminated zone (m**2) ³ 4.000E+03 ³ 1.000E+04 ³ --- ³ AREA
R011 ³ Thickness of contaminated zone (m) ³ 1.500E-01 ³ 2.000E+00 ³ --- ³ THICK0
R011 ³ Length parallel to aquifer flow (m) ³ 1.000E+02 ³ 1.000E+02 ³ --- ³ LCZPAQ
R011 ³ Basic radiation dose limit (mrem/yr) ³ 2.500E+01 ³ 3.000E+01 ³ --- ³ BRDL
R011 ³ Time since placement of material (yr) ³ 0.000E+00 ³ 0.000E+00 ³ --- ³ TI
R011 ³ Times for calculations (yr) ³ 1.000E+00 ³ 1.000E+00 ³ --- ³ T(2)
R011 ³ Times for calculations (yr) ³ 3.000E+00 ³ 3.000E+00 ³ --- ³ T(3)
R011 ³ Times for calculations (yr) ³ 1.000E+01 ³ 1.000E+01 ³ --- ³ T(4)
R011 ³ Times for calculations (yr) ³ 3.000E+01 ³ 3.000E+01 ³ --- ³ T(5)
R011 ³ Times for calculations (yr) ³ 1.000E+02 ³ 1.000E+02 ³ --- ³ T(6)
R011 ³ Times for calculations (yr) ³ 3.000E+02 ³ 3.000E+02 ³ --- ³ T(7)
R011 ³ Times for calculations (yr) ³ 1.000E+03 ³ 1.000E+03 ³ --- ³ T(8)
R011 ³ Times for calculations (yr) ³ not used ³ 0.000E+00 ³ --- ³ T(9)
R011 ³ Times for calculations (yr) ³ not used ³ 0.000E+00 ³ --- ³ T(10)
³ ³ ³ ³ ³
R012 ³ Initial principal radionuclide (pCi/g): Pb-210 ³ 1.000E+00 ³ 0.000E+00 ³ --- ³ S1(1)
R012 ³ Initial principal radionuclide (pCi/g): Po-210 ³ 1.000E+00 ³ 0.000E+00 ³ --- ³ S1(2)
R012 ³ Initial principal radionuclide (pCi/g): Ra-226 ³ 1.000E+00 ³ 0.000E+00 ³ --- ³ S1(3)
R012 ³ Initial principal radionuclide (pCi/g): Th-230 ³ 1.000E+00 ³ 0.000E+00 ³ --- ³ S1(4)
R012 ³ Initial principal radionuclide (pCi/g): U-234 ³ 1.000E+00 ³ 0.000E+00 ³ --- ³ S1(5)
R012 ³ Initial principal radionuclide (pCi/g): U-238 ³ 1.000E+00 ³ 0.000E+00 ³ --- ³ S1(6)
R012 ³ Concentration in groundwater (pCi/L): Pb-210 ³ not used ³ 0.000E+00 ³ --- ³ W1(1)
R012 ³ Concentration in groundwater (pCi/L): Po-210 ³ not used ³ 0.000E+00 ³ --- ³ W1(2)
R012 ³ Concentration in groundwater (pCi/L): Ra-226 ³ not used ³ 0.000E+00 ³ --- ³ W1(3)
R012 ³ Concentration in groundwater (pCi/L): Th-230 ³ not used ³ 0.000E+00 ³ --- ³ W1(4)
R012 ³ Concentration in groundwater (pCi/L): U-234 ³ not used ³ 0.000E+00 ³ --- ³ W1(5)
R012 ³ Concentration in groundwater (pCi/L): U-238 ³ not used ³ 0.000E+00 ³ --- ³ W1(6)

³ ³ ³ ³ ³

R013 ³ Cover depth (m) ³ 0.000E+00 ³ 0.000E+00 ³ --- ³ COVER0
R013 ³ Density of cover material (g/cm**3) ³ not used ³ 1.500E+00 ³ --- ³ DENSCV
R013 ³ Cover depth erosion rate (m/yr) ³ not used ³ 1.000E-03 ³ --- ³ VCV
R013 ³ Density of contaminated zone (g/cm**3) ³ 1.500E+00 ³ 1.500E+00 ³ --- ³ DENSCZ
R013 ³ Contaminated zone erosion rate (m/yr) ³ 1.000E-03 ³ 1.000E-03 ³ --- ³ VCZ
R013 ³ Contaminated zone total porosity ³ 4.000E-01 ³ 4.000E-01 ³ --- ³ TPCZ
R013 ³ Contaminated zone field capacity ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ FCCZ
R013 ³ Contaminated zone hydraulic conductivity (m/yr) ³ 1.000E+01 ³ 1.000E+01 ³ --- ³ HCCZ
R013 ³ Contaminated zone b parameter ³ 5.300E+00 ³ 5.300E+00 ³ --- ³ BCZ
R013 ³ Average annual wind speed (m/sec) ³ 2.000E+00 ³ 2.000E+00 ³ --- ³ WIND
R013 ³ Humidity in air (g/m**3) ³ not used ³ 8.000E+00 ³ --- ³ HUMID
R013 ³ Evapotranspiration coefficient ³ 5.000E-01 ³ 5.000E-01 ³ --- ³ EVAPTR
R013 ³ Precipitation (m/yr) ³ 1.000E+00 ³ 1.000E+00 ³ --- ³ PRECIP
R013 ³ Irrigation (m/yr) ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ RI
R013 ³ Irrigation mode ³ overhead ³ overhead ³ --- ³ IDITCH
R013 ³ Runoff coefficient ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ RUNOFF
R013 ³ Watershed area for nearby stream or pond (m**2) ³ 1.000E+06 ³ 1.000E+06 ³ --- ³ WAREA
R013 ³ Accuracy for water/soil computations ³ 1.000E-03 ³ 1.000E-03 ³ --- ³ EPS

³ ³ ³ ³ ³

R014 ³ Density of saturated zone (g/cm**3) ³ 1.500E+00 ³ 1.500E+00 ³ --- ³ DENSAQ
R014 ³ Saturated zone total porosity ³ 4.000E-01 ³ 4.000E-01 ³ --- ³ TPSZ
R014 ³ Saturated zone effective porosity ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ EPSZ
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Site-Specific Parameter Summary (continued)
0 ³ ³ User ³ ³ Used by RESRAD ³ Parameter
Menu ³ Parameter ³ Input ³ Default ³ (If different from user input) ³ Name

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R014 ³ Saturated zone field capacity ³ 2.000E-01 ³ 2.000E-01 ³ --- ³ FCSZ
R014 ³ Saturated zone hydraulic conductivity (m/yr) ³ 1.000E+02 ³ 1.000E+02 ³ --- ³ HCSZ

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R014 ³ Saturated zone hydraulic gradient          ³ 2.000E-02 ³ 2.000E-02 ³     ---      ³ HGWT
R014 ³ Saturated zone b parameter                 ³ 5.300E+00 ³ 5.300E+00 ³     ---      ³ BSZ
R014 ³ Water table drop rate (m/yr)               ³ 1.000E-03 ³ 1.000E-03 ³     ---      ³ VWT
R014 ³ Well pump intake depth (m below water table) ³ 1.000E+01 ³ 1.000E+01 ³   ---      ³ DWIBWT
R014 ³ Model: Nondispersion (ND) or Mass-Balance (MB) ³ ND      ³ ND        ³     ---      ³ MODEL
R014 ³ Well pumping rate (m**3/yr)                ³ 2.500E+02 ³ 2.500E+02 ³     ---      ³ UW
     ³                                            ³           ³           ³              ³
R015 ³ Number of unsaturated zone strata          ³ 1         ³ 1         ³     ---      ³ NS
R015 ³ Unsat. zone 1, thickness (m)               ³ 4.000E+00 ³ 4.000E+00 ³     ---      ³ H(1)
R015 ³ Unsat. zone 1, soil density (g/cm**3)      ³ 1.500E+00 ³ 1.500E+00 ³     ---      ³ DENSUZ(1)
R015 ³ Unsat. zone 1, total porosity              ³ 4.000E-01 ³ 4.000E-01 ³     ---      ³ TPUZ(1)
R015 ³ Unsat. zone 1, effective porosity          ³ 2.000E-01 ³ 2.000E-01 ³     ---      ³ EPUZ(1)
R015 ³ Unsat. zone 1, field capacity              ³ 2.000E-01 ³ 2.000E-01 ³     ---      ³ FCUZ(1)
R015 ³ Unsat. zone 1, soil-specific b parameter   ³ 5.300E+00 ³ 5.300E+00 ³     ---      ³ BUZ(1)
R015 ³ Unsat. zone 1, hydraulic conductivity (m/yr) ³ 1.000E+01 ³ 1.000E+01 ³   ---      ³ HCUZ(1)
     ³                                            ³           ³           ³              ³
R016 ³ Distribution coefficients for Pb-210       ³           ³           ³              ³
R016 ³   Contaminated zone (cm**3/g)              ³ 1.000E+02 ³ 1.000E+02 ³     ---      ³ DCNUCC( 1)
R016 ³   Unsaturated zone 1 (cm**3/g)             ³ 1.000E+02 ³ 1.000E+02 ³     ---      ³ DCNUCU( 1,1)
R016 ³   Saturated zone (cm**3/g)                 ³ 1.000E+02 ³ 1.000E+02 ³     ---      ³ DCNUCS( 1)
R016 ³   Leach rate (/yr)                         ³ 0.000E+00 ³ 0.000E+00 ³   2.217E-02  ³ ALEACH( 1)
R016 ³   Solubility constant                      ³ 0.000E+00 ³ 0.000E+00 ³   not used   ³ SOLUBK( 1)
     ³                                            ³           ³           ³              ³
R016 ³ Distribution coefficients for Po-210       ³           ³           ³              ³
R016 ³   Contaminated zone (cm**3/g)              ³ 1.000E+01 ³ 1.000E+01 ³     ---      ³ DCNUCC( 2)
R016 ³   Unsaturated zone 1 (cm**3/g)             ³ 1.000E+01 ³ 1.000E+01 ³     ---      ³ DCNUCU( 2,1)
R016 ³   Saturated zone (cm**3/g)                 ³ 1.000E+01 ³ 1.000E+01 ³     ---      ³ DCNUCS( 2)
R016 ³   Leach rate (/yr)                         ³ 0.000E+00 ³ 0.000E+00 ³   2.176E-01  ³ ALEACH( 2)
R016 ³   Solubility constant                      ³ 0.000E+00 ³ 0.000E+00 ³   not used   ³ SOLUBK( 2)
     ³                                            ³           ³           ³              ³
R016 ³ Distribution coefficients for Ra-226       ³           ³           ³              ³
R016 ³   Contaminated zone (cm**3/g)              ³ 7.000E+01 ³ 7.000E+01 ³     ---      ³ DCNUCC( 3)
R016 ³   Unsaturated zone 1 (cm**3/g)             ³ 7.000E+01 ³ 7.000E+01 ³     ---      ³ DCNUCU( 3,1)
R016 ³   Saturated zone (cm**3/g)                 ³ 7.000E+01 ³ 7.000E+01 ³     ---      ³ DCNUCS( 3)
R016 ³   Leach rate (/yr)                         ³ 0.000E+00 ³ 0.000E+00 ³   3.165E-02  ³ ALEACH( 3)
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R016 ³  Solubility constant                  ³ 0.000E+00 ³ 0.000E+00 ³      not used       ³ SOLUBK( 3)
     ³                              ³   ³        ³          ³
R016 ³ Distribution coefficients for Th-230  ³       ³       ³                     ³
R016 ³  Contaminated zone (cm**3/g)          ³ 6.000E+04 ³ 6.000E+04 ³        ---          ³ DCNUCC( 4)
R016 ³  Unsaturated zone 1 (cm**3/g)         ³ 6.000E+04 ³ 6.000E+04 ³        ---          ³ DCNUCU( 4,1)
R016 ³  Saturated zone (cm**3/g)             ³ 6.000E+04 ³ 6.000E+04 ³        ---          ³ DCNUCS( 4)
R016 ³  Leach rate (/yr)                     ³ 0.000E+00 ³ 0.000E+00 ³     3.704E-05       ³ ALEACH( 4)
R016 ³  Solubility constant                  ³ 0.000E+00 ³ 0.000E+00 ³      not used       ³ SOLUBK( 4)
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 Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
 File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

                   Site-Specific Parameter Summary (continued)
0    ³                                 ³   User    ³           ³  Used by RESRAD     ³ Parameter
 Menu ³            Parameter           ³   Input   ³  Default  ³ (If different from user input) ³  Name

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R016 ³ Distribution coefficients for U-234   ³       ³       ³                     ³
R016 ³  Contaminated zone (cm**3/g)          ³ 5.000E+01 ³ 5.000E+01 ³        ---          ³ DCNUCC( 5)
R016 ³  Unsaturated zone 1 (cm**3/g)         ³ 5.000E+01 ³ 5.000E+01 ³        ---          ³ DCNUCU( 5,1)
R016 ³  Saturated zone (cm**3/g)             ³ 5.000E+01 ³ 5.000E+01 ³        ---          ³ DCNUCS( 5)
R016 ³  Leach rate (/yr)                     ³ 0.000E+00 ³ 0.000E+00 ³     4.426E-02       ³ ALEACH( 5)
R016 ³  Solubility constant                  ³ 0.000E+00 ³ 0.000E+00 ³      not used       ³ SOLUBK( 5)
     ³                              ³   ³        ³          ³
R016 ³ Distribution coefficients for U-238   ³       ³       ³                     ³
R016 ³  Contaminated zone (cm**3/g)          ³ 5.000E+01 ³ 5.000E+01 ³        ---          ³ DCNUCC( 6)
R016 ³  Unsaturated zone 1 (cm**3/g)         ³ 5.000E+01 ³ 5.000E+01 ³        ---          ³ DCNUCU( 6,1)
R016 ³  Saturated zone (cm**3/g)             ³ 5.000E+01 ³ 5.000E+01 ³        ---          ³ DCNUCS( 6)
R016 ³  Leach rate (/yr)                     ³ 0.000E+00 ³ 0.000E+00 ³     4.426E-02       ³ ALEACH( 6)
R016 ³  Solubility constant                  ³ 0.000E+00 ³ 0.000E+00 ³      not used       ³ SOLUBK( 6)
     ³                              ³   ³        ³          ³
R017 ³ Inhalation rate (m**3/yr)             ³ 8.400E+03 ³ 8.400E+03 ³        ---          ³ INHALR
R017 ³ Mass loading for inhalation (g/m**3)  ³ 1.000E-04 ³ 1.000E-04 ³        ---          ³ MLINH
R017 ³ Exposure duration                     ³ 3.000E+01 ³ 3.000E+01 ³        ---          ³ ED
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R017 ³ Shielding factor, inhalation ³ 4.000E-01 ³ 4.000E-01 ³ --- ³ SHF3
R017 ³ Shielding factor, external gamma ³ 7.000E-01 ³ 7.000E-01 ³ --- ³ SHF1
R017 ³ Fraction of time spent indoors ³ 5.000E-01 ³ 5.000E-01 ³ --- ³ FIND
R017 ³ Fraction of time spent outdoors (on site) ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ FOTD
R017 ³ Shape factor flag, external gamma ³ 1.000E+00 ³ 1.000E+00 ³ >0 shows circular AREA. ³ FS
R017 ³ Radii of shape factor array (used if FS = -1): ³ ³ ³ ³
R017 ³ Outer annular radius (m), ring 1: ³ not used ³ 5.000E+01 ³ --- ³ RAD_SHAPE(1)
R017 ³ Outer annular radius (m), ring 2: ³ not used ³ 7.071E+01 ³ --- ³ RAD_SHAPE(2)
R017 ³ Outer annular radius (m), ring 3: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(3)
R017 ³ Outer annular radius (m), ring 4: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(4)
R017 ³ Outer annular radius (m), ring 5: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(5)
R017 ³ Outer annular radius (m), ring 6: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(6)
R017 ³ Outer annular radius (m), ring 7: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(7)
R017 ³ Outer annular radius (m), ring 8: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(8)
R017 ³ Outer annular radius (m), ring 9: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(9)
R017 ³ Outer annular radius (m), ring 10: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(10)
R017 ³ Outer annular radius (m), ring 11: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(11)
R017 ³ Outer annular radius (m), ring 12: ³ not used ³ 0.000E+00 ³ --- ³ RAD_SHAPE(12)
³ ³ ³ ³ ³

R017 ³ Fractions of annular areas within AREA: ³ ³ ³ ³
R017 ³ Ring 1 ³ not used ³ 1.000E+00 ³ --- ³ FRACA(1)
R017 ³ Ring 2 ³ not used ³ 2.732E-01 ³ --- ³ FRACA(2)
R017 ³ Ring 3 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(3)
R017 ³ Ring 4 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(4)
R017 ³ Ring 5 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(5)
R017 ³ Ring 6 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(6)
R017 ³ Ring 7 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(7)
R017 ³ Ring 8 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(8)
R017 ³ Ring 9 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(9)
R017 ³ Ring 10 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(10)
R017 ³ Ring 11 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(11)
R017 ³ Ring 12 ³ not used ³ 0.000E+00 ³ --- ³ FRACA(12)
³ ³ ³ ³ ³

1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 7
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn

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                    Site-Specific Parameter Summary (continued)
0    ³                          ³ User   ³          ³ Used by RESRAD              ³ Parameter
Menu ³           Parameter              ³ Input    ³ Default  ³ (If different from user input) ³ Name
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R018 ³ Fruits, vegetables and grain consumption (kg/yr) ³ 2.000E+00 ³ 1.600E+02 ³     ---     ³ DIET(1)
R018 ³ Leafy vegetable consumption (kg/yr)       ³ 2.000E+00 ³ 1.400E+01 ³     ---     ³ DIET(2)
R018 ³ Milk consumption (L/yr)                   ³ 9.200E+01 ³ 9.200E+01 ³     ---     ³ DIET(3)
R018 ³ Meat and poultry consumption (kg/yr)      ³ 6.300E+01 ³ 6.300E+01 ³     ---     ³ DIET(4)
R018 ³ Fish consumption (kg/yr)                  ³ 5.400E+00 ³ 5.400E+00 ³     ---     ³ DIET(5)
R018 ³ Other seafood consumption (kg/yr)         ³ 9.000E-01 ³ 9.000E-01 ³     ---     ³ DIET(6)
R018 ³ Soil ingestion rate (g/yr)                ³ 3.650E+01 ³ 3.650E+01 ³     ---     ³ SOIL
R018 ³ Drinking water intake (L/yr)              ³ not used  ³ 5.100E+02 ³     ---     ³ DWI
R018 ³ Contamination fraction of drinking water  ³ not used  ³ 1.000E+00 ³     ---     ³ FDW
R018 ³ Contamination fraction of household water ³ not used  ³ 1.000E+00 ³     ---     ³ FHHW
R018 ³ Contamination fraction of livestock water ³ 0.000E+00 ³ 1.000E+00 ³     ---     ³ FLW
R018 ³ Contamination fraction of irrigation water ³ 0.000E+00 ³ 1.000E+00 ³     ---     ³ FIRW
R018 ³ Contamination fraction of aquatic food    ³ 5.000E-01 ³ 5.000E-01 ³     ---     ³ FR9
R018 ³ Contamination fraction of plant food      ³-1         ³-1         ³ 0.500E+00   ³ FPLANT
R018 ³ Contamination fraction of meat            ³-1         ³-1         ³ 0.200E+00   ³ FMEAT
R018 ³ Contamination fraction of milk            ³-1         ³-1         ³ 0.200E+00   ³ FMILK
     ³                                           ³           ³           ³
R019 ³ Livestock fodder intake for meat (kg/day) ³ 6.800E+01 ³ 6.800E+01 ³     ---     ³ LFI5
R019 ³ Livestock fodder intake for milk (kg/day) ³ 5.500E+01 ³ 5.500E+01 ³     ---     ³ LFI6
R019 ³ Livestock water intake for meat (L/day)   ³ 5.000E+01 ³ 5.000E+01 ³     ---     ³ LWI5
R019 ³ Livestock water intake for milk (L/day)   ³ 1.600E+02 ³ 1.600E+02 ³     ---     ³ LWI6
R019 ³ Livestock soil intake (kg/day)            ³ 5.000E-01 ³ 5.000E-01 ³     ---     ³ LSI
R019 ³ Mass loading for foliar deposition (g/m**3) ³ 1.000E-04 ³ 1.000E-04 ³     ---     ³ MLFD
R019 ³ Depth of soil mixing layer (m)            ³ 1.500E-01 ³ 1.500E-01 ³     ---     ³ DM
R019 ³ Depth of roots (m)                        ³ 9.000E-01 ³ 9.000E-01 ³     ---     ³ DROOT
R019 ³ Drinking water fraction from ground water ³ not used  ³ 1.000E+00 ³     ---     ³ FGWDW
R019 ³ Household water fraction from ground water ³ not used  ³ 1.000E+00 ³     ---     ³ FGWHH
```

R019 ³ Livestock water fraction from ground water ³ 0.000E+00 ³ 1.000E+00 ³ --- ³ FGWLW
R019 ³ Irrigation fraction from ground water ³ 0.000E+00 ³ 1.000E+00 ³ --- ³ FGWIR
³ ³ ³ ³ ³

R19B ³ Wet weight crop yield for Non-Leafy (kg/m**2) ³ 7.000E-01 ³ 7.000E-01 ³ --- ³ YV(1)
R19B ³ Wet weight crop yield for Leafy (kg/m**2) ³ 1.500E+00 ³ 1.500E+00 ³ --- ³ YV(2)
R19B ³ Wet weight crop yield for Fodder (kg/m**2) ³ 1.100E+00 ³ 1.100E+00 ³ --- ³ YV(3)
R19B ³ Growing Season for Non-Leafy (years) ³ 1.700E-01 ³ 1.700E-01 ³ --- ³ TE(1)
R19B ³ Growing Season for Leafy (years) ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ TE(2)
R19B ³ Growing Season for Fodder (years) ³ 8.000E-02 ³ 8.000E-02 ³ --- ³ TE(3)
R19B ³ Translocation Factor for Non-Leafy ³ 1.000E-01 ³ 1.000E-01 ³ --- ³ TIV(1)
R19B ³ Translocation Factor for Leafy ³ 1.000E+00 ³ 1.000E+00 ³ --- ³ TIV(2)
R19B ³ Translocation Factor for Fodder ³ 1.000E+00 ³ 1.000E+00 ³ --- ³ TIV(3)
R19B ³ Dry Foliar Interception Fraction for Non-Leafy ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ RDRY(1)
R19B ³ Dry Foliar Interception Fraction for Leafy ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ RDRY(2)
R19B ³ Dry Foliar Interception Fraction for Fodder ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ RDRY(3)
R19B ³ Wet Foliar Interception Fraction for Non-Leafy ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ RWET(1)
R19B ³ Wet Foliar Interception Fraction for Leafy ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ RWET(2)
R19B ³ Wet Foliar Interception Fraction for Fodder ³ 2.500E-01 ³ 2.500E-01 ³ --- ³ RWET(3)
R19B ³ Weathering Removal Constant for Vegetation ³ 2.000E+01 ³ 2.000E+01 ³ --- ³ WLAM
³ ³ ³ ³ ³

C14 ³ C-12 concentration in water (g/cm**3) ³ not used ³ 2.000E-05 ³ --- ³ C12WTR
C14 ³ C-12 concentration in contaminated soil (g/g) ³ not used ³ 3.000E-02 ³ --- ³ C12CZ
C14 ³ Fraction of vegetation carbon from soil ³ not used ³ 2.000E-02 ³ --- ³ CSOIL
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 8
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Site-Specific Parameter Summary (continued)
0 ³ ³ User ³ ³ Used by RESRAD ³ Parameter
Menu ³ Parameter ³ Input ³ Default ³ (If different from user input) ³ Name

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C14 ³ Fraction of vegetation carbon from air ³ not used ³ 9.800E-01 ³ --- ³ CAIR
C14 ³ C-14 evasion layer thickness in soil (m) ³ not used ³ 3.000E-01 ³ --- ³ DMC

```
C14  ³ C-14 evasion flux rate from soil (1/sec)      ³ not used  ³ 7.000E-07 ³      ---      ³ EVSN
C14  ³ C-12 evasion flux rate from soil (1/sec)      ³ not used  ³ 1.000E-10 ³      ---      ³ REVSN
C14  ³ Fraction of grain in beef cattle feed         ³ not used  ³ 8.000E-01 ³      ---      ³ AVFG4
C14  ³ Fraction of grain in milk cow feed            ³ not used  ³ 2.000E-01 ³      ---      ³ AVFG5
     ³                                               ³           ³           ³               ³
STOR ³ Storage times of contaminated foodstuffs (days): ³        ³           ³               ³
STOR ³   Fruits, non-leafy vegetables, and grain     ³ 1.400E+01 ³ 1.400E+01 ³      ---      ³ STOR_T(1)
STOR ³   Leafy vegetables                            ³ 1.000E+00 ³ 1.000E+00 ³      ---      ³ STOR_T(2)
STOR ³   Milk                                        ³ 1.000E+00 ³ 1.000E+00 ³      ---      ³ STOR_T(3)
STOR ³   Meat and poultry                            ³ 2.000E+01 ³ 2.000E+01 ³      ---      ³ STOR_T(4)
STOR ³   Fish                                        ³ 7.000E+00 ³ 7.000E+00 ³      ---      ³ STOR_T(5)
STOR ³   Crustacea and mollusks                      ³ 7.000E+00 ³ 7.000E+00 ³      ---      ³ STOR_T(6)
STOR ³   Well water                                  ³ 1.000E+00 ³ 1.000E+00 ³      ---      ³ STOR_T(7)
STOR ³   Surface water                               ³ 1.000E+00 ³ 1.000E+00 ³      ---      ³ STOR_T(8)
STOR ³   Livestock fodder                            ³ 4.500E+01 ³ 4.500E+01 ³      ---      ³ STOR_T(9)
     ³                                               ³           ³           ³               ³
R021 ³ Thickness of building foundation (m)          ³ not used  ³ 1.500E-01 ³      ---      ³ FLOOR1
R021 ³ Bulk density of building foundation (g/cm**3) ³ not used  ³ 2.400E+00 ³      ---      ³ DENSFL
R021 ³ Total porosity of the cover material          ³ not used  ³ 4.000E-01 ³      ---      ³ TPCV
R021 ³ Total porosity of the building foundation     ³ not used  ³ 1.000E-01 ³      ---      ³ TPFL
R021 ³ Volumetric water content of the cover material ³ not used ³ 5.000E-02 ³      ---      ³ PH2OCV
R021 ³ Volumetric water content of the foundation    ³ not used  ³ 3.000E-02 ³      ---      ³ PH2OFL
R021 ³ Diffusion coefficient for radon gas (m/sec):  ³           ³           ³               ³
R021 ³   in cover material                           ³ not used  ³ 2.000E-06 ³      ---      ³ DIFCV
R021 ³   in foundation material                      ³ not used  ³ 3.000E-07 ³      ---      ³ DIFFL
R021 ³   in contaminated zone soil                   ³ not used  ³ 2.000E-06 ³      ---      ³ DIFCZ
R021 ³ Radon vertical dimension of mixing (m)        ³ not used  ³ 2.000E+00 ³      ---      ³ HMIX
R021 ³ Average building air exchange rate (1/hr)     ³ not used  ³ 5.000E-01 ³      ---      ³ REXG
R021 ³ Height of the building (room) (m)             ³ not used  ³ 2.500E+00 ³      ---      ³ HRM
R021 ³ Building interior area factor                 ³ not used  ³ 0.000E+00 ³      ---      ³ FAI
R021 ³ Building depth below ground surface (m)       ³ not used  ³-1.000E+00 ³      ---      ³ DMFL
R021 ³ Emanating power of Rn-222 gas                 ³ not used  ³ 2.500E-01 ³      ---      ³ EMANA(1)
R021 ³ Emanating power of Rn-220 gas                 ³ not used  ³ 1.500E-01 ³      ---      ³ EMANA(2)
     ³                                               ³           ³           ³               ³
TITL ³ Number of graphical time points               ³    32     ³    ---    ³      ---      ³ NPTS
```

```
TITL ³ Maximum number of integration points for dose  ³  17  ³  ---  ³      ---       ³ LYMAX
TITL ³ Maximum number of integration points for risk  ³   1  ³  ---  ³      ---       ³ KYMAX
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Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD



          Summary of Pathway Selections

          Pathway            ³  User Selection
      ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
       1 -- external gamma       ³  active
       2 -- inhalation (w/o radon)³  active
       3 -- plant ingestion      ³  active
       4 -- meat ingestion       ³  active
       5 -- milk ingestion       ³  active
       6 -- aquatic foods        ³  active
       7 -- drinking water       ³  suppressed
       8 -- soil ingestion       ³  active
       9 -- radon                ³  suppressed
       Find peak pathway doses   ³  suppressed
      ÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ
1RESRAD, Version 6.4     T« Limit = 30 days     05/07/2009  18:24  Page  10
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

   Contaminated Zone Dimensions      Initial Soil Concentrations, pCi/g
   ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ      ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
    Area:  4000.00 square meters       Pb-210   1.000E+00
  Thickness:    0.15 meters            Po-210   1.000E+00
Cover Depth:    0.00 meters            Ra-226   1.000E+00
                                       Th-230   1.000E+00
```

U-234 1.000E+00
U-238 1.000E+00
0

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

ÄÄ

t (years): 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
TDOSE(t): 5.923E+00 5.722E+00 5.347E+00 4.216E+00 2.127E+00 1.871E-01 3.386E-15 1.099E-01
M(t): 2.369E-01 2.289E-01 2.139E-01 1.686E-01 8.507E-02 7.484E-03 1.354E-16 4.397E-03
0Maximum TDOSE(t): 5.923E+00 mrem/yr at t = 0.000E+00 years
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 11
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 3.330E-03 0.0006 1.054E-03 0.0002 0.000E+00 0.0000 1.792E-02 0.0030 6.134E-02 0.0104 2.026E-02 0.0034 1.689E-01
0.0285
Po-210 1.130E-05 0.0000 2.323E-04 0.0000 0.000E+00 0.0000 2.737E-04 0.0000 2.623E-02 0.0044 2.573E-03 0.0004 2.208E-02
0.0037
Ra-226 5.358E+00 0.9046 5.062E-04 0.0001 0.000E+00 0.0000 1.760E-02 0.0030 1.657E-02 0.0028 2.104E-02 0.0036
3.799E-02 0.0064
Th-230 1.851E-03 0.0003 1.892E-02 0.0032 0.000E+00 0.0000 1.884E-04 0.0000 3.551E-04 0.0001 2.973E-05 0.0000 1.496E-02
0.0025
U-234 2.251E-04 0.0000 7.494E-03 0.0013 0.000E+00 0.0000 2.315E-04 0.0000 6.265E-04 0.0001 1.594E-03 0.0003 7.553E-03

0.0013
U-238 7.693E-02 0.0130 6.702E-03 0.0011 0.000E+00 0.0000 2.198E-04 0.0000 5.949E-04 0.0001 1.514E-03 0.0003 7.172E-03
0.0012
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Total 5.440E+00 0.9185 3.491E-02 0.0059 0.000E+00 0.0000 3.644E-02 0.0062 1.057E-01 0.0178 4.701E-02 0.0079 2.587E-01
0.0437
0
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.728E-01 0.0461
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.140E-02 0.0087
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.452E+00 0.9204
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
3.630E-02 0.0061
U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.772E-02 0.0030
U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
9.313E-02 0.0157
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.923E+00 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 12
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 3.164E-03 0.0006 1.166E-03 0.0002 0.000E+00 0.0000 1.711E-02 0.0030 7.710E-02 0.0135 2.103E-02 0.0037 1.756E-01
0.0307
Po-210 1.456E-06 0.0000 2.981E-05 0.0000 0.000E+00 0.0000 3.517E-05 0.0000 3.379E-03 0.0006 3.302E-04 0.0001 2.832E-03
0.0005
Ra-226 5.177E+00 0.9048 5.217E-04 0.0001 0.000E+00 0.0000 1.747E-02 0.0031 1.818E-02 0.0032 2.089E-02 0.0037
4.188E-02 0.0073
Th-230 4.127E-03 0.0007 1.879E-02 0.0033 0.000E+00 0.0000 1.947E-04 0.0000 3.601E-04 0.0001 3.852E-05 0.0000 1.488E-02
0.0026
U-234 2.153E-04 0.0000 7.122E-03 0.0012 0.000E+00 0.0000 2.200E-04 0.0000 5.957E-04 0.0001 1.515E-03 0.0003 7.178E-03
0.0013
U-238 7.348E-02 0.0128 6.369E-03 0.0011 0.000E+00 0.0000 2.089E-04 0.0000 5.656E-04 0.0001 1.439E-03 0.0003 6.815E-03
0.0012
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Total 5.258E+00 0.9189 3.400E-02 0.0059 0.000E+00 0.0000 3.525E-02 0.0062 1.002E-01 0.0175 4.524E-02 0.0079 2.492E-01
0.0435
0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.951E-01 0.0516
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
6.608E-03 0.0012
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.276E+00 0.9221
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
3.839E-02 0.0067
U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.685E-02 0.0029
U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
8.887E-02 0.0155
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.722E+00 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 13
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 2.843E-03 0.0005 1.058E-03 0.0002 0.000E+00 0.0000 1.521E-02 0.0028 7.108E-02 0.0133 1.892E-02 0.0035 1.580E-01
0.0295
Po-210 2.417E-08 0.0000 4.902E-07 0.0000 0.000E+00 0.0000 5.783E-07 0.0000 5.556E-05 0.0000 5.429E-06 0.0000 4.658E-05
0.0000
Ra-226 4.833E+00 0.9039 5.495E-04 0.0001 0.000E+00 0.0000 1.713E-02 0.0032 2.129E-02 0.0040 2.053E-02 0.0038
4.875E-02 0.0091

000324

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Th-230  8.435E-03 0.0016  1.854E-02 0.0035  0.000E+00 0.0000  2.070E-04 0.0000  3.723E-04 0.0001  5.582E-05 0.0000  1.471E-02
0.0028
U-234  1.972E-04 0.0000  6.431E-03 0.0012  0.000E+00 0.0000  1.987E-04 0.0000  5.379E-04 0.0001  1.368E-03 0.0003  6.482E-03
0.0012
U-238  6.703E-02 0.0125  5.751E-03 0.0011  0.000E+00 0.0000  1.886E-04 0.0000  5.107E-04 0.0001  1.299E-03 0.0002  6.154E-03
0.0012
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Total  4.911E+00 0.9186  3.233E-02 0.0060  0.000E+00 0.0000  3.293E-02 0.0062  9.385E-02 0.0176  4.217E-02 0.0079  2.341E-01
0.0438
0
         Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                  As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0                          Water Dependent Pathways
0        Water        Fish        Radon        Plant        Meat        Milk        All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.
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Pb-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
2.671E-01 0.0499
Po-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.087E-04 0.0000
Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
4.941E+00 0.9241
Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
4.232E-02 0.0079
U-234  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.521E-02 0.0028
U-238  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
8.093E-02 0.0151
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Total  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
5.347E+00 1.0000
0*Sum of all water independent and dependent pathways.
```

U_chain_4e3m2_ 15_2kg vegetables_-GW_-Rn.txt
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 14
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 1.950E-03 0.0005 6.943E-04 0.0002 0.000E+00 0.0000 9.974E-03 0.0024 4.665E-02 0.0111 1.241E-02 0.0029 1.036E-01
0.0246
Po-210 1.423E-14 0.0000 2.791E-13 0.0000 0.000E+00 0.0000 3.293E-13 0.0000 3.164E-11 0.0000 3.092E-12 0.0000 2.652E-11
0.0000
Ra-226 3.795E+00 0.9001 5.808E-04 0.0001 0.000E+00 0.0000 1.537E-02 0.0036 2.714E-02 0.0064 1.852E-02 0.0044
6.139E-02 0.0146
Th-230 2.120E-02 0.0050 1.765E-02 0.0042 0.000E+00 0.0000 2.452E-04 0.0001 4.278E-04 0.0001 1.111E-04 0.0000 1.417E-02
0.0034
U-234 1.453E-04 0.0000 4.494E-03 0.0011 0.000E+00 0.0000 1.388E-04 0.0000 3.758E-04 0.0001 9.556E-04 0.0002 4.528E-03
0.0011
U-238 4.856E-02 0.0115 4.017E-03 0.0010 0.000E+00 0.0000 1.318E-04 0.0000 3.568E-04 0.0001 9.074E-04 0.0002 4.299E-03
0.0010
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Total 3.867E+00 0.9172 2.744E-02 0.0065 0.000E+00 0.0000 2.586E-02 0.0061 7.495E-02 0.0178 3.291E-02 0.0078 1.880E-01
0.0446
0
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Nuclide mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.
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 Pb-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.753E-01 0.0416
 Po-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
6.187E-11 0.0000
 Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
3.918E+00 0.9293
 Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
5.380E-02 0.0128
 U-234   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
1.064E-02 0.0025
 U-238   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
5.827E-02 0.0138
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 Total   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
4.216E+00 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4      T« Limit = 30 days       05/07/2009  18:24  Page  15
 Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
 File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

           Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                     As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
0                         Water Independent Pathways (Inhalation excludes radon)
0        Ground        Inhalation        Radon        Plant        Meat        Milk        Soil
 Radio-  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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 Nuclide mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.  mrem/yr fract.
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 Pb-210  6.615E-04 0.0003  2.050E-04 0.0001  0.000E+00 0.0000  2.945E-03 0.0014  1.378E-02 0.0065  3.664E-03 0.0017  3.060E-02
0.0144
 Po-210  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  4.489E-29 0.0000  4.386E-30 0.0000
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3.763E-29 0.0000
Ra-226 1.882E+00 0.8848 4.206E-04 0.0002 0.000E+00 0.0000 9.211E-03 0.0043 2.290E-02 0.0108 1.119E-02 0.0053
5.137E-02 0.0242
Th-230 4.282E-02 0.0201 1.511E-02 0.0071 0.000E+00 0.0000 3.074E-04 0.0001 5.772E-04 0.0003 2.131E-04 0.0001 1.260E-02
0.0059
U-234 6.357E-05 0.0000 1.590E-03 0.0007 0.000E+00 0.0000 4.909E-05 0.0000 1.329E-04 0.0001 3.378E-04 0.0002 1.602E-03
0.0008
U-238 1.917E-02 0.0090 1.420E-03 0.0007 0.000E+00 0.0000 4.659E-05 0.0000 1.261E-04 0.0001 3.208E-04 0.0002 1.520E-03
0.0007
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Total 1.944E+00 0.9143 1.875E-02 0.0088 0.000E+00 0.0000 1.256E-02 0.0059 3.752E-02 0.0176 1.573E-02 0.0074 9.769E-02
0.0459
0
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.185E-02 0.0244
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
8.690E-29 0.0000
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.977E+00 0.9295
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
7.163E-02 0.0337
U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
3.776E-03 0.0018
U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.260E-02 0.0106
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.127E+00 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 16
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 1.336E-05 0.0001 2.041E-06 0.0000 0.000E+00 0.0000 2.934E-05 0.0002 1.373E-04 0.0007 3.650E-05 0.0002 3.047E-04
0.0016
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 1.254E-01 0.6701 2.864E-05 0.0002 0.000E+00 0.0000 5.505E-04 0.0029 1.691E-03 0.0090 6.732E-04 0.0036 3.774E-03
0.0202
Th-230 4.124E-02 0.2204 6.241E-03 0.0334 0.000E+00 0.0000 1.803E-04 0.0010 3.875E-04 0.0021 1.531E-04 0.0008 5.537E-03
0.0296
U-234 1.004E-05 0.0001 3.095E-05 0.0002 0.000E+00 0.0000 9.516E-07 0.0000 2.557E-06 0.0000 6.345E-06 0.0000 3.102E-05
0.0002
U-238 5.895E-04 0.0032 2.657E-05 0.0001 0.000E+00 0.0000 8.716E-07 0.0000 2.361E-06 0.0000 6.001E-06 0.0000 2.843E-05
0.0002
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Total 1.672E-01 0.8938 6.329E-03 0.0338 0.000E+00 0.0000 7.620E-04 0.0041 2.221E-03 0.0119 8.751E-04 0.0047 9.676E-03
0.0517
0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
0 Water Dependent Pathways

U_chain_4e3m2_ 15_2kg vegetables_-GW_-Rn.txt
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.233E-04 0.0028
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.321E-01 0.7060
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
5.374E-02 0.2873
U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
8.186E-05 0.0004
U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
6.537E-04 0.0035
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.871E-01 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 17
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
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Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
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Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
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U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
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U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
0
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 0.000E+00 0.0000 1.284E-23 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.284E-23 0.0000
Th-230 0.000E+00 0.0000 1.729E-26 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.729E-26 0.0000
U-234 0.000E+00 0.0000 3.386E-15 1.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
3.386E-15 1.0000

U-238 0.000E+00 0.0000 1.817E-20 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.817E-20 0.0000
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Total 0.000E+00 0.0000 3.386E-15 1.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
3.386E-15 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 18
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
0 Water Independent Pathways (Inhalation excludes radon)
0 Ground Inhalation Radon Plant Meat Milk Soil
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Th-230 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
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U-234 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
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U-238 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
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Total 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
0

U_chain_4e3m2_ 15_2kg vegetables_-GW_-Rn.txt
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
0 Water Dependent Pathways
0 Water Fish Radon Plant Meat Milk All Pathways*
Radio- ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
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Nuclide mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract. mrem/yr fract.
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Pb-210 0.000E+00 0.0000 4.606E-15 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
4.606E-15 0.0000
Po-210 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
0.000E+00 0.0000
Ra-226 0.000E+00 0.0000 1.066E-01 0.9698 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.066E-01 0.9698
Th-230 0.000E+00 0.0000 3.044E-03 0.0277 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
3.044E-03 0.0277
U-234 0.000E+00 0.0000 2.426E-04 0.0022 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.426E-04 0.0022
U-238 0.000E+00 0.0000 2.975E-05 0.0003 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
2.975E-05 0.0003
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Total 0.000E+00 0.0000 1.099E-01 1.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000 0.000E+00 0.0000
1.099E-01 1.0000
0*Sum of all water independent and dependent pathways.
1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 19
Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated
0 Parent Product Thread DSR(j,t) At Time in Years (mrem/yr)/(pCi/g)
(i) (j) Fraction 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
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Pb-210+D	Pb-210+D	1.000E+00	2.138E-01	2.014E-01	1.786E-01	1.172E-01	3.470E-02	3.524E-04	0.000E+00	1.219E-16
Pb-210+D	Po-210	1.000E+00	5.905E-02	9.378E-02	8.845E-02	5.808E-02	1.715E-02	1.709E-04	0.000E+00	4.485E-15
Pb-210+D	äDSR(j)		2.728E-01	2.951E-01	2.671E-01	1.753E-01	5.185E-02	5.233E-04	0.000E+00	4.606E-15
0Po-210	Po-210	1.000E+00	5.140E-02	6.608E-03	1.087E-04	6.187E-11	8.779E-29	0.000E+00	0.000E+00	0.000E+00
0Ra-226+D	Ra-226+D	1.000E+00	5.448E+00	5.263E+00	4.912E+00	3.855E+00	1.908E+00	1.264E-01	0.000E+00	2.864E-04
Ra-226+D	Pb-210+D	1.000E+00	3.476E-03	9.698E-03	2.032E-02	4.296E-02	4.628E-02	3.829E-03	0.000E+00	2.860E-03
Ra-226+D	Po-210	1.000E+00	7.007E-04	3.204E-03	8.502E-03	2.009E-02	2.233E-02	1.833E-03	1.284E-23	1.035E-01
Ra-226+D	äDSR(j)		5.452E+00	5.276E+00	4.941E+00	3.918E+00	1.977E+00	1.321E-01	1.284E-23	1.066E-01
0Th-230	Th-230	1.000E+00	3.512E-02	3.489E-02	3.442E-02	3.280E-02	2.816E-02	1.190E-02	0.000E+00	0.000E+00
Th-230	Ra-226+D	1.000E+00	1.185E-03	3.499E-03	7.877E-03	2.084E-02	4.275E-02	4.106E-02	0.000E+00	8.180E-06
Th-230	Pb-210+D	1.000E+00	5.111E-07	3.381E-06	1.642E-05	1.144E-04	4.911E-04	5.311E-04	0.000E+00	8.166E-05
Th-230	Po-210	1.000E+00	8.236E-08	8.929E-07	5.982E-06	5.054E-05	2.309E-04	2.500E-04	1.729E-26	2.954E-03
Th-230	äDSR(j)		3.630E-02	3.839E-02	4.232E-02	5.380E-02	7.163E-02	5.374E-02	1.729E-26	3.044E-03
0U-234	U-234	1.000E+00	1.772E-02	1.685E-02	1.521E-02	1.063E-02	3.767E-03	7.162E-05	0.000E+00	3.091E-05
U-234	Th-230	1.000E+00	1.561E-07	4.556E-07	1.005E-06	2.480E-06	4.245E-06	2.395E-06	0.000E+00	2.511E-09
U-234	Ra-226+D	1.000E+00	3.523E-09	2.410E-08	1.208E-07	8.928E-07	4.416E-06	7.714E-06	0.000E+00	6.070E-07
U-234	Pb-210+D	1.000E+00	1.153E-12	1.633E-11	1.733E-10	3.462E-09	3.921E-08	9.337E-08	0.000E+00	5.657E-06
U-234	Po-210	1.000E+00	1.553E-13	3.655E-12	5.641E-11	1.463E-09	1.817E-08	4.386E-08	3.386E-15	2.054E-04
U-234	äDSR(j)		1.772E-02	1.685E-02	1.521E-02	1.064E-02	3.776E-03	8.186E-05	3.386E-15	2.426E-04
0U-238	U-238	5.400E-05	8.518E-07	8.095E-07	7.310E-07	5.107E-07	1.807E-07	3.401E-09	0.000E+00	1.508E-09
0U-238+D	U-238+D	9.999E-01	9.313E-02	8.887E-02	8.093E-02	5.827E-02	2.260E-02	6.537E-04	0.000E+00	2.943E-05
U-238+D	U-234	9.999E-01	2.491E-08	7.143E-08	1.508E-07	3.164E-07	3.257E-07	2.041E-08	0.000E+00	8.778E-08
U-238+D	Th-230	9.999E-01	1.466E-13	9.923E-13	4.886E-12	3.408E-11	1.435E-10	1.454E-10	0.000E+00	4.978E-12
U-238+D	Ra-226+D	9.999E-01	2.483E-15	3.626E-14	3.977E-13	8.432E-12	1.092E-10	4.209E-10	0.000E+00	7.135E-10
U-238+D	Pb-210+D	9.999E-01	6.541E-19	1.917E-17	4.367E-16	2.520E-14	7.805E-13	4.671E-12	0.000E+00	6.428E-09
U-238+D	Po-210	9.999E-01	7.567E-20	3.749E-18	1.287E-16	1.020E-14	3.563E-13	2.188E-12	1.817E-20	2.310E-07
U-238+D	äDSR(j)		9.313E-02	8.887E-02	8.093E-02	5.827E-02	2.260E-02	6.537E-04	1.817E-20	2.975E-05

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The DSR includes contributions from associated (half-life ó 30 days) daughters.

1RESRAD, Version 6.4 T« Limit = 30 days 05/07/2009 18:24 Page 20

Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn

File : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

Single Radionuclide Soil Guidelines G(i,t) in pCi/g

Basic Radiation Dose Limit = 2.500E+01 mrem/yr

```
0Nuclide
 (i)  t= 0.000E+00  1.000E+00  3.000E+00  1.000E+01  3.000E+01  1.000E+02  3.000E+02  1.000E+03
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 Pb-210    9.163E+01  8.470E+01  9.361E+01  1.426E+02  4.821E+02  4.778E+04 *7.634E+13 *7.634E+13
 Po-210    4.864E+02  3.784E+03  2.301E+05  4.041E+11 *4.494E+15 *4.494E+15 *4.494E+15 *4.494E+15
 Ra-226    4.586E+00  4.738E+00  5.060E+00  6.381E+00  1.265E+01  1.893E+02 *9.885E+11  2.345E+02
 Th-230    6.886E+02  6.512E+02  5.907E+02  4.647E+02  3.490E+02  4.652E+02 *2.018E+10  8.213E+03
 U-234     1.410E+03  1.484E+03  1.643E+03  2.350E+03  6.621E+03  3.054E+05 *6.247E+09  1.030E+05
 U-238     2.685E+02  2.813E+02  3.089E+02  4.290E+02  1.106E+03  3.824E+04 *3.361E+05 *3.361E+05
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 *At specific activity limit
0
         Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
         and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
       at tmin = time of minimum single radionuclide soil guideline
    and at tmax = time of maximum total dose = 0.000E+00 years
0Nuclide  Initial     tmin     DSR(i,tmin) G(i,tmin) DSR(i,tmax) G(i,tmax)
 (i)   (pCi/g)    (years)              (pCi/g)            (pCi/g)
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 Pb-210  1.000E+00   0.814 ñ 0.002   2.957E-01  8.454E+01  2.728E-01  9.163E+01
 Po-210  1.000E+00   0.000E+00       5.140E-02  4.864E+02  5.140E-02  4.864E+02
 Ra-226  1.000E+00   0.000E+00       5.452E+00  4.586E+00  5.452E+00  4.586E+00
 Th-230  1.000E+00   46.83 ñ 0.09    7.525E-02  3.322E+02  3.630E-02  6.886E+02
 U-234   1.000E+00   0.000E+00       1.772E-02  1.410E+03  1.772E-02  1.410E+03
 U-238   1.000E+00   0.000E+00       9.313E-02  2.685E+02  9.313E-02  2.685E+02
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1RESRAD, Version 6.4      T« Limit = 30 days      05/07/2009  18:24  Page  21
 Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
 File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

                    Individual Nuclide Dose Summed Over All Pathways
                      Parent Nuclide and Branch Fraction Indicated
0Nuclide Parent   THF(i)                       DOSE(j,t), mrem/yr
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 (j)    (i)          t= 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
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 Pb-210  Pb-210  1.000E+00   2.138E-01 2.014E-01 1.786E-01 1.172E-01 3.470E-02 3.524E-04 0.000E+00 1.219E-16
 Pb-210  Ra-226  1.000E+00   3.476E-03 9.698E-03 2.032E-02 4.296E-02 4.628E-02 3.829E-03 0.000E+00 2.860E-03
 Pb-210  Th-230  1.000E+00   5.111E-07 3.381E-06 1.642E-05 1.144E-04 4.911E-04 5.311E-04 0.000E+00 8.166E-05
 Pb-210  U-234   1.000E+00   1.153E-12 1.633E-11 1.733E-10 3.462E-09 3.921E-08 9.337E-08 0.000E+00 5.657E-06
 Pb-210  U-238   9.999E-01   6.541E-19 1.917E-17 4.367E-16 2.520E-14 7.805E-13 4.671E-12 0.000E+00 6.428E-09
 Pb-210  äDOSE(j)            2.173E-01 2.111E-01 1.990E-01 1.603E-01 8.148E-02 4.713E-03 0.000E+00 2.948E-03
0Po-210  Pb-210  1.000E+00   5.905E-02 9.378E-02 8.845E-02 5.808E-02 1.715E-02 1.709E-04 0.000E+00 4.485E-15
 Po-210  Po-210  1.000E+00   5.140E-02 6.608E-03 1.087E-04 6.187E-11 8.690E-29 0.000E+00 0.000E+00 0.000E+00
 Po-210  Ra-226  1.000E+00   7.007E-04 3.204E-03 8.502E-03 2.009E-02 2.233E-02 1.833E-03 1.284E-23 1.035E-01
 Po-210  Th-230  1.000E+00   8.236E-08 8.929E-07 5.982E-06 5.054E-05 2.309E-04 2.500E-04 1.729E-26 2.954E-03
 Po-210  U-234   1.000E+00   1.553E-13 3.655E-12 5.641E-11 1.463E-09 1.817E-08 4.386E-08 3.386E-15 2.054E-04
 Po-210  U-238   9.999E-01   7.567E-20 3.749E-18 1.287E-16 1.020E-14 3.563E-13 2.188E-12 1.817E-20 2.310E-07
 Po-210  äDOSE(j)            1.111E-01 1.036E-01 9.706E-02 7.822E-02 3.971E-02 2.254E-03 3.386E-15 1.066E-01
0Ra-226  Ra-226  1.000E+00   5.448E+00 5.263E+00 4.912E+00 3.855E+00 1.908E+00 1.264E-01 0.000E+00 2.864E-04
 Ra-226  Th-230  1.000E+00   1.185E-03 3.499E-03 7.877E-03 2.084E-02 4.275E-02 4.106E-02 0.000E+00 8.180E-06
 Ra-226  U-234   1.000E+00   3.523E-09 2.410E-08 1.208E-07 8.928E-07 4.416E-06 7.714E-06 0.000E+00 6.070E-07
 Ra-226  U-238   9.999E-01   2.483E-15 3.626E-14 3.977E-13 8.432E-12 1.092E-10 4.209E-10 0.000E+00 7.135E-10
 Ra-226  äDOSE(j)            5.449E+00 5.267E+00 4.920E+00 3.876E+00 1.951E+00 1.675E-01 0.000E+00 2.952E-04
0Th-230  Th-230  1.000E+00   3.512E-02 3.489E-02 3.442E-02 3.280E-02 2.816E-02 1.190E-02 0.000E+00 0.000E+00
 Th-230  U-234   1.000E+00   1.561E-07 4.556E-07 1.005E-06 2.480E-06 4.245E-06 2.395E-06 0.000E+00 2.511E-09
 Th-230  U-238   9.999E-01   1.466E-13 9.923E-13 4.886E-12 3.408E-11 1.435E-10 1.454E-10 0.000E+00 4.978E-12
 Th-230  äDOSE(j)            3.512E-02 3.489E-02 3.442E-02 3.280E-02 2.817E-02 1.190E-02 0.000E+00 2.516E-09
0U-234   U-234   1.000E+00   1.772E-02 1.685E-02 1.521E-02 1.063E-02 3.767E-03 7.162E-05 0.000E+00 3.091E-05
 U-234   U-238   9.999E-01   2.491E-08 7.143E-08 1.508E-07 3.164E-07 3.257E-07 2.041E-08 0.000E+00 8.778E-08
 U-234   äDOSE(j)            1.772E-02 1.685E-02 1.521E-02 1.063E-02 3.767E-03 7.164E-05 0.000E+00 3.099E-05
0U-238   U-238   5.400E-05   8.518E-07 8.095E-07 7.310E-07 5.107E-07 1.807E-07 3.401E-09 0.000E+00 1.508E-09
 U-238   U-238   9.999E-01   9.313E-02 8.887E-02 8.093E-02 5.827E-02 2.260E-02 6.537E-04 0.000E+00 2.943E-05
 U-238   äDOSE(j)            9.313E-02 8.887E-02 8.093E-02 5.827E-02 2.260E-02 6.537E-04 0.000E+00 2.943E-05
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THF(i) is the thread fraction of the parent nuclide.
1RESRAD, Version 6.4      T« Limit = 30 days      05/07/2009  18:24  Page  22
 Summary : U_chain_4e3m2_.15_2kg vegetables_-GW_-Rn
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File    : C:\RESRAD_FAMILY\RESRAD\USERFILES\NONNUC_UCHAIN_4E3M2.RAD

                    Individual Nuclide Soil Concentration
                   Parent Nuclide and Branch Fraction Indicated
0Nuclide Parent  THF(i)                      S(j,t), pCi/g
 (j)    (i)       t= 0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
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 Pb-210  Pb-210  1.000E+00   1.000E+00 9.481E-01 8.523E-01 5.871E-01 2.024E-01 4.865E-03 1.151E-07 7.422E-24
 Pb-210  Ra-226  1.000E+00   0.000E+00 2.978E-02 8.206E-02 2.032E-01 2.636E-01 5.220E-02 9.682E-05 1.712E-14
 Pb-210  Th-230  1.000E+00   0.000E+00 6.544E-06 5.567E-05 5.096E-04 2.725E-03 7.118E-03 7.789E-03 7.544E-03
 Pb-210  U-234   1.000E+00   0.000E+00 1.956E-11 4.951E-10 1.467E-08 2.143E-07 1.249E-06 1.585E-06 1.536E-06
 Pb-210  U-238   9.999E-01   0.000E+00 1.383E-17 1.045E-15 1.014E-13 4.199E-12 6.229E-11 1.015E-10 9.849E-11
 Pb-210  äS(j):              1.000E+00 9.779E-01 9.345E-01 7.908E-01 4.687E-01 6.419E-02 7.888E-03 7.545E-03
0Po-210  Pb-210  1.000E+00   0.000E+00 7.515E-01 7.801E-01 5.387E-01 1.857E-01 4.464E-03 1.056E-07 6.810E-24
 Po-210  Po-210  1.000E+00   1.000E+00 1.291E-01 2.152E-03 1.287E-09 2.131E-27 0.000E+00 0.000E+00 0.000E+00
 Po-210  Ra-226  1.000E+00   0.000E+00 1.545E-02 6.247E-02 1.762E-01 2.365E-01 4.733E-02 8.790E-05 1.554E-14
 Po-210  Th-230  1.000E+00   0.000E+00 2.579E-06 3.653E-05 4.181E-04 2.385E-03 6.352E-03 6.962E-03 6.742E-03
 Po-210  U-234   1.000E+00   0.000E+00 6.275E-12 2.881E-10 1.152E-08 1.851E-07 1.112E-06 1.417E-06 1.373E-06
 Po-210  U-238   9.999E-01   0.000E+00 3.751E-18 5.469E-16 7.633E-14 3.574E-12 5.533E-11 9.073E-11 8.802E-11
 Po-210  äS(j):              1.000E+00 8.961E-01 8.448E-01 7.154E-01 4.246E-01 5.814E-02 7.051E-03 6.743E-03
0Ra-226  Ra-226  1.000E+00   1.000E+00 9.684E-01 9.082E-01 7.256E-01 3.819E-01 4.043E-02 6.607E-05 1.166E-14
 Ra-226  Th-230  1.000E+00   0.000E+00 4.263E-04 1.239E-03 3.705E-03 8.339E-03 1.291E-02 1.334E-02 1.291E-02
 Ra-226  U-234   1.000E+00   0.000E+00 1.901E-09 1.626E-08 1.518E-07 8.512E-07 2.423E-06 2.715E-06 2.629E-06
 Ra-226  U-238   9.999E-01   0.000E+00 1.788E-15 4.546E-14 1.367E-12 2.076E-11 1.319E-10 1.740E-10 1.686E-10
 Ra-226  äS(j):              1.000E+00 9.689E-01 9.095E-01 7.293E-01 3.903E-01 5.334E-02 1.341E-02 1.292E-02
0Th-230  Th-230  1.000E+00   1.000E+00 1.000E+00 9.999E-01 9.995E-01 9.986E-01 9.954E-01 9.863E-01 9.550E-01
 Th-230  U-234   1.000E+00   0.000E+00 8.805E-06 2.529E-05 7.272E-05 1.494E-04 2.002E-04 2.008E-04 1.944E-04
 Th-230  U-238   9.999E-01   0.000E+00 1.239E-11 1.052E-10 9.551E-10 4.987E-09 1.215E-08 1.288E-08 1.247E-08
 Th-230  äS(j):              1.000E+00 1.000E+00 9.999E-01 9.996E-01 9.988E-01 9.956E-01 9.865E-01 9.552E-01
0U-234   U-234   1.000E+00   1.000E+00 9.567E-01 8.757E-01 6.424E-01 2.651E-01 1.196E-02 1.713E-06 6.012E-20
 U-234   U-238   9.999E-01   0.000E+00 2.712E-06 7.447E-06 1.821E-05 2.254E-05 3.392E-06 1.457E-09 1.707E-22
 U-234   äS(j):              1.000E+00 9.567E-01 8.757E-01 6.424E-01 2.651E-01 1.197E-02 1.714E-06 6.029E-20
0U-238   U-238   5.400E-05   5.400E-05 5.166E-05 4.729E-05 3.469E-05 1.432E-05 6.463E-07 9.257E-11 3.256E-24
 U-238   U-238   9.999E-01   9.999E-01 9.567E-01 8.756E-01 6.424E-01 2.651E-01 1.197E-02 1.714E-06 6.029E-20
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U-238 äS(j): 1.000E+00 9.567E-01 8.757E-01 6.424E-01 2.651E-01 1.197E-02 1.714E-06 6.029E-20
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THF(i) is the thread fraction of the parent nuclide.
0RESCALC.EXE execution time = 3.67 seconds

GENERAL FIELD
SAMPLING GUIDELINES

SOP#: 2001
DATE: 08/11/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide general field sampling guidelines that will assist REAC personnel in choosing sampling strategies, location, and frequency for proper assessment of site characteristics. This SOP is applicable to all field activities that involve sampling.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

Sampling is the selection of a representative portion of a larger population, universe, or body. Through examination of a sample, the characteristics of the larger body from which the sample was drawn can be inferred. In this manner, sampling can be a valuable tool for determining the presence, type, and extent of contamination by hazardous substances in the environment.

The primary objective of all sampling activities is to characterize a hazardous waste site accurately so that its impact on human health and the environment can be properly evaluated. It is only through sampling and analysis that site hazards can be measured and the job of cleanup and restoration can be accomplished effectively with minimal risk. The sampling itself must be conducted so that every sample collected retains its original physical form and chemical composition. In this way, sample integrity is insured, quality assurance standards are maintained, and the sample can accurately represent the larger body of material under investigation.

The extent to which valid inferences can be drawn from a sample depends on the degree to which the sampling effort conforms to the project's objectives. For example, as few as one sample may produce adequate, technically valid data to address the project's objectives. Meeting the project's objectives requires thorough planning of sampling activities, and implementation of the most appropriate sampling and analytical procedures. These issues will be discussed in this procedure.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The amount of sample to be collected, and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. Sample preservation, containers, handling, and storage for air and waste samples are discussed in the specific SOPs for air and waste sampling techniques.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

The nature of the object or materials being sampled may be a potential problem to the sampler. If a material is homogeneous, it will generally have a uniform composition throughout. In this case, any sample increment can be considered representative of the material. On the other hand, heterogeneous samples present problems to the sampler because of changes in the material over distance, both laterally and vertically.

Samples of hazardous materials may pose a safety threat to both field and laboratory personnel. Proper health and safety precautions should be implemented when handling this type of sample.

Environmental conditions, weather conditions, or non-target chemicals may cause problems and/or interferences when performing sampling activities or when sampling for a specific parameter. Refer to the specific SOPs for sampling techniques.

5.0 EQUIPMENT/APPARATUS

The equipment/apparatus required to collect samples must be determined on a site specific basis. Due to the wide variety of sampling equipment available, refer to the specific SOPs for sampling techniques which include lists of the equipment/apparatus required for sampling.

6.0 REAGENTS

Reagents may be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

7.0 PROCEDURE

7.1 Types of Samples

In relation to the media to be sampled, two basic types of samples can be considered: the environmental sample and the hazardous sample.

Environmental samples are those collected from streams, ponds, lakes, wells, and are off-site samples that are not expected to be contaminated with hazardous materials. They usually do not require the special handling procedures typically used for concentrated wastes. However, in certain instances, environmental samples can contain elevated concentrations of pollutants and in such cases would have to be handled as hazardous samples.

Hazardous or concentrated samples are those collected from drums, tanks, lagoons, pits, waste piles, fresh spills, or areas previously identified as contaminated, and require special handling procedures because of their potential toxicity or hazard. These samples can be further subdivided based on their degree of hazard; however, care should be taken when handling and shipping any wastes believed to be concentrated regardless of the degree.

The importance of making the distinction between environmental and hazardous samples is two-fold:

(1) Personnel safety requirements: Any sample thought to contain enough hazardous materials to pose a safety threat should be designated as hazardous and handled in a manner which ensures the safety of both field and laboratory personnel.

(2) Transportation requirements: Hazardous samples must be packaged, labeled, and shipped according to the International Air Transport Association (IATA) Dangerous Goods Regulations or Department of Transportation (DOT) regulations and U.S. EPA guidelines.

7.2 Sample Collection Techniques

In general, two basic types of sample collection techniques are recognized, both of which can be used for either environmental or hazardous samples.

Grab Samples

A grab sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected all at once at one particular point in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

Composite Samples

Composites are nondiscrete samples composed of more than one specific aliquot collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

Compositing is often used for environmental samples and may be used for hazardous samples under certain conditions. For example, compositing of hazardous waste is often performed after compatibility tests have been completed to determine an average value over a number of different locations (group of drums). This procedure generates data that can be useful by providing an average concentration within a number of units, can serve to keep analytical costs down, and can provide information useful to transporters and waste disposal operations.

For sampling situations involving hazardous wastes, grab sampling techniques are generally preferred because grab sampling minimizes the amount of time sampling personnel must be in contact with the wastes, reduces risks associated with compositing unknowns, and eliminates chemical changes that might occur due to compositing.

7.3 Types of Sampling Strategies

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling.

Random sampling involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site. Systematic sampling involves collection of samples based on a grid or a pattern which has been previously established. When judgmental sampling is performed, samples are collected only from the portion(s) of the site most likely to be contaminated. Often, a combination of these strategies is the best approach depending on the type of the suspected/known contamination, the uniformity and size of the site, the level/type of information desired, etc.

7.4 QA Work Plans (QAWP)

A QAWP is required when it becomes evident that a field investigation is necessary. It should be initiated in conjunction with, or immediately following, notification of the field investigation. This plan should be clear and concise and should detail the following basic components, with regard to sampling activities:

- Objective and purpose of the investigation.
- Basis upon which data will be evaluated.
- Information known about the site including location, type and size of the facility, and length of operations/abandonment.
- Type and volume of contaminated material, contaminants of concern (including concentration), and basis of the information/data.
- Technical approach including media/matrix to be sampled, sampling equipment to be used, sample equipment decontamination (if necessary), sampling design and rationale, and SOPs or description of the procedure to be implemented.
- Project management and reporting, schedule, project organization and responsibilities, manpower and cost projections, and required deliverables.
- QA objectives and protocols including tables summarizing field sampling and QA/QC analysis and objectives.

Note that this list of QAWP components is not all-inclusive and that additional elements may be added or altered depending on the specific requirements of the field investigation. It should also be recognized that although a detailed QAWP is quite important, it may be impractical in some instances. Emergency responses and accidental spills are prime examples of such instances where time might prohibit the development of site-specific QAWPs prior to field activities. In such cases, investigators would have to rely on general guidelines and personal judgment, and the sampling or response plans might simply be a strategy based on preliminary information and finalized on site. In any event, a plan of action should be developed, no matter how concise or informal, to aid investigators in maintaining a logical and consistent order to the implementation of their task.

7.5 Legal Implications

The data derived from sampling activities are often introduced as critical evidence during litigation of a hazardous waste site cleanup. Legal issues in which sampling data are important may include cleanup cost recovery, identification of pollution sources and responsible parties, and technical validation of remedial design methodologies. Because of the potential for involvement in legal actions, strict adherence to technical and administrative SOPs is essential during both the development and implementation of sampling activities.

Technically valid sampling begins with thorough planning and continues through the sample collection and analytical procedures. Administrative requirements involve thorough, accurate documentation of all sampling activities. Documentation requirements include maintenance of a chain of custody, as well as accurate records of field activities and analytical instructions. Failure to observe these procedures fully and consistently may result in data that are questionable, invalid and non-defensible in court, and the consequent loss of enforcement proceedings.

8.0 CALCULATIONS

Refer to the specific SOPs for any calculations which are associated with sampling techniques.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

Refer to the specific SOPs for the type and frequency of QA/QC samples to be analyzed, the acceptance criteria for the QA/QC samples, and any other QA/QC activities which are associated with sampling techniques.

10.0 DATA VALIDATION

Refer to the specific SOPs for data validation activities that are associated with sampling techniques.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety procedures.

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide a description of the methods used for preventing, minimizing, or limiting cross-contamination of samples due to inappropriate or inadequate equipment decontamination and to provide general guidelines for developing decontamination procedures for sampling equipment to be used during hazardous waste operations as per 29 Code of Federal Regulations (CFR) 1910.120. This SOP does not address personnel decontamination.

These are standard (i.e. typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitation, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Removing or neutralizing contaminants from equipment minimizes the likelihood of sample cross contamination, reduces or eliminates transfer of contaminants to clean areas, and prevents the mixing of incompatible substances.

Gross contamination can be removed by physical decontamination procedures. These abrasive and non-abrasive methods include the use of brushes, air and wet blasting, and high and low pressure water cleaning.

The first step, a soap and water wash, removes all visible particulate matter and residual oils and grease. This may be preceded by a steam or high pressure water wash to facilitate residuals removal. The second step involves a tap water rinse and a distilled/deionized water rinse to remove the detergent. An acid rinse provides a low pH media for trace metals removal and is included in the decontamination process if metal samples are to be collected. It is followed by another distilled/deionized water rinse. If sample analysis does not include metals, the acid rinse step can be omitted. Next, a high purity solvent rinse is performed for trace organics removal if organics are a concern at the site. Typical solvents used for removal of organic contaminants include acetone, hexane, or water. Acetone is typically chosen because it is an excellent solvent, miscible in water, and not a target analyte on the Priority Pollutant List. If acetone is known to be a contaminant of concern at a given site or if Target Compound List analysis (which includes acetone) is to be performed, another solvent may be substituted. The solvent must be allowed to evaporate completely and then a final distilled/deionized water rinse is performed. This rinse removes any residual traces of the solvent.

The decontamination procedure described above may be summarized as follows:

1. Physical removal
2. Non-phosphate detergent wash
3. Tap water rinse
4. Distilled/deionized water rinse
5. 10% nitric acid rinse
6. Distilled/deionized water rinse
7. Solvent rinse (pesticide grade)
8. Air dry
9. Distilled/deionized water rinse

If a particular contaminant fraction is not present at the site, the nine (9) step decontamination procedure specified above may be modified for site specificity. For example, the nitric acid rinse may be eliminated if metals are not of concern at a site. Similarly, the solvent rinse may be eliminated if organics are not of concern at a site. Modifications to the standard procedure should be documented in the site specific work plan or subsequent report.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The amount of sample to be collected and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest.

More specifically, sample collection and analysis of decontamination waste may be required before beginning proper disposal of decontamination liquids and solids generated at a site. This should be determined prior to initiation of site activities.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

C The use of distilled/deionized water commonly available from commercial vendors may be acceptable for decontamination of sampling equipment provided that it has been verified by laboratory analysis to be analyte free (specifically for the contaminants of concern).

C The use of an untreated potable water supply is not an acceptable substitute for tap water. Tap water may be used from any municipal or industrial water treatment system.

C If acids or solvents are utilized in decontamination they raise health and safety, and waste disposal concerns.

C Damage can be incurred by acid and solvent washing of complex and sophisticated sampling equipment.

5.0 EQUIPMENT/APPARATUS

Decontamination equipment, materials, and supplies are generally selected based on availability. Other considerations include the ease of decontaminating or disposing of the equipment. Most equipment and supplies can be easily procured. For example, soft-bristle scrub brushes or long-handled bottle brushes can be used to remove contaminants. Large galvanized wash tubs, stock tanks, or buckets can hold wash and rinse solutions. Children's wading pools can also be used. Large plastic garbage cans or other similar containers lined with plastic bags can help segregate contaminated equipment. Contaminated liquid can be stored temporarily in metal or plastic cans or drums.

The following standard materials and equipment are recommended for decontamination activities:

5.1 Decontamination Solutions

- Non-phosphate detergent
- Selected solvents (acetone, hexane, nitric acid, etc.)
- Tap water
- Distilled or deionized water

5.2 Decontamination Tools/Supplies

- Long and short handled brushes
- Bottle brushes
- Drop cloth/plastic sheeting
- Paper towels
- Plastic or galvanized tubs or buckets
- Pressurized sprayers (H_2O)
- Solvent sprayers
- Aluminum foil

5.3 Health and Safety Equipment

Appropriate personal protective equipment (i.e., safety glasses or splash shield, appropriate gloves, aprons or coveralls, respirator, emergency eye wash)

5.4 Waste Disposal

- Trash bags
- Trash containers
- 55-gallon drums
- Metal/plastic buckets/containers for storage and disposal of decontamination solutions

6.0 REAGENTS

There are no reagents used in this procedure aside from the actual decontamination solutions. Table 1 (Appendix A) lists solvent rinses which may be required for elimination of particular chemicals. In general, the following solvents are typically utilized for decontamination purposes:

- 10% nitric acid is typically used for inorganic compounds such as metals. An acid rinse may not be required if inorganics are not a contaminant of concern.
- Acetone (pesticide grade)[1]
- Hexane (pesticide grade)[1]
- Methanol[1]

[1] - Only if sample is to be analyzed for organics.

7.0 PROCEDURES

As part of the health and safety plan, a decontamination plan should be developed and reviewed. The decontamination line should be set up before any personnel or equipment enter the areas of potential exposure. The equipment decontamination plan should include:

- The number, location, and layout of decontamination stations.

- Decontamination equipment needed.

- Appropriate decontamination methods.

- Methods for disposal of contaminated clothing, equipment, and solutions.

- Procedures can be established to minimize the potential for contamination. This may include: (1) work practices that minimize contact with potential contaminants; (2) using remote sampling techniques; (3) covering monitoring and sampling equipment with plastic, aluminum foil, or other protective material; (4) watering down dusty areas; (5) avoiding laying down equipment in areas of obvious contamination; and (6) use of disposable sampling equipment.

7.1 Decontamination Methods

All samples and equipment leaving the contaminated area of a site must be decontaminated to remove any contamination that may have adhered to equipment. Various decontamination methods will remove contaminants by: (1) flushing or other physical action, or (2) chemical complexing to inactivate contaminants by neutralization, chemical reaction, disinfection, or sterilization.

Physical decontamination techniques can be grouped into two categories: abrasive methods and non-abrasive methods, as follows:

7.1.1 Abrasive Cleaning Methods

Abrasive cleaning methods work by rubbing and wearing away the top layer of the surface containing the contaminant. The mechanical abrasive cleaning methods are most commonly used at hazardous waste sites. The following abrasive methods are available:

Mechanical

Mechanical methods of decontamination include using metal or nylon brushes. The amount and type of contaminants removed will vary with the hardness of bristles, length of time brushed, degree of brush contact, degree of contamination, nature of the surface being cleaned, and degree of contaminant adherence to the surface.

Air Blasting

Air blasting equipment uses compressed air to force abrasive material through a nozzle at high velocities. The distance between nozzle and surface cleaned, air pressure, time of application, and angle at which the abrasive strikes the surface will dictate cleaning efficiency. Disadvantages of this method are the inability to control the amount of material removed and the large amount of waste generated.

Wet Blasting

Wet blast cleaning involves use of a suspended fine abrasive. The abrasive/water mixture is delivered by compressed air to the contaminated area. By using a very fine abrasive, the amount of materials removed can be carefully controlled.

7.1.2 Non-Abrasive Cleaning Methods

Non-abrasive cleaning methods work by forcing the contaminant off a surface with pressure. In general, the equipment surface is not removed using non-abrasive methods.

Low-Pressure Water

This method consists of a container which is filled with water. The user pumps air out of the container to create a vacuum. A slender nozzle and hose allow the user to spray in hard-to-reach places.

High-Pressure Water

This method consists of a high-pressure pump, an operator controlled directional nozzle, and a high-pressure hose. Operating pressure usually ranges from 340 to 680 atmospheres (atm) and flow rates usually range from 20 to 140 liters per minute.

Ultra-High-Pressure Water

This system produces a water jet that is pressured from 1,000 to 4,000 atmospheres. This ultra-high-pressure spray can remove tightly-adhered surface films. The water velocity ranges from 500 meters/second (m/s) (1,000 atm) to 900 m/s (4,000 atm). Additives can be used to enhance the cleaning action.

Rinsing

Contaminants are removed by rinsing through dilution, physical attraction, and solubilization.

Damp Cloth Removal

In some instances, due to sensitive, non-waterproof equipment or due to the unlikelihood of equipment being contaminated, it is not necessary to conduct an extensive decontamination procedure. For example, air sampling pumps hooked on a fence, placed on a drum, or wrapped in plastic bags are not likely to become heavily contaminated. A damp cloth should be used to wipe off contaminants which may have adhered to equipment through airborne contaminants or from surfaces upon which the equipment was set.

Disinfection/Sterilization

Disinfectants are a practical means of inactivating infectious agents. Unfortunately, standard sterilization methods are impractical for large equipment. This method of decontamination is typically performed off-site.

7.2 Field Sampling Equipment Decontamination Procedures

The decontamination line is setup so that the first station is used to clean the most contaminated item. It progresses to the last station where the least contaminated item is cleaned. The spread of contaminants is further reduced by separating each decontamination station by a minimum of three (3) feet. Ideally, the contamination should decrease as the equipment progresses from one station to another farther along in the line.

A site is typically divided up into the following boundaries: Hot Zone or Exclusion Zone (EZ), the Contamination Reduction Zone (CRZ), and the Support or Safe Zone (SZ). The decontamination line should be setup in the Contamination Reduction Corridor (CRC) which is in the CRZ. Figure 1 (Appendix B) shows a typical contaminant reduction zone layout. The CRC controls access into and out of the exclusion zone and confines decontamination activities to a limited area. The CRC boundaries should be conspicuously marked. The far end is the hotline, the boundary between the exclusion zone and the contamination reduction zone. The size of the decontamination corridor depends on the number of stations in the decontamination process, overall dimensions of the work zones, and amount of space available at the site. Whenever possible, it should be a straight line.

Anyone in the CRC should be wearing the level of protection designated for the decontamination crew. Another corridor may be required for the entry and exit of heavy equipment. Sampling and monitoring equipment and sampling supplies are all maintained outside of the CRC. Personnel don their equipment away from the CRC and enter the exclusion zone through a separate access control point at the hotline. One person (or more) dedicated to decontaminating equipment is recommended.

7.2.1 Decontamination Setup

Starting with the most contaminated station, the decontamination setup should be as follows:

Station 1: Segregate Equipment Drop

Place plastic sheeting on the ground (Figure 2, Appendix B). Size will depend on amount of equipment to be decontaminated. Provide containers lined with plastic if equipment is to be segregated. Segregation may be required if sensitive equipment or mildly contaminated equipment is used at the same time as equipment which is likely to be heavily contaminated.

Station 2: Physical Removal With A High-Pressure

Washer (Optional)

As indicated in 7.1.2, a high-pressure wash may be required for compounds which are difficult to remove by washing with brushes. The elevated temperature of the water from the high-pressure washers is excellent at removing greasy/oily compounds. High pressure washers require water and electricity.

A decontamination pad may be required for the high-pressure wash area. An example of a wash pad may consist of an approximately 1 1/2 foot-deep basin lined with plastic sheeting and sloped to a sump at one corner. A layer of sand can be placed over the plastic and the basin is filled with gravel or shell. The sump is also lined with visqueen and a barrel is placed in the hole to prevent collapse. A sump pump is used to remove the water from the sump for transfer into a drum.

Typically heavy machinery is decontaminated at the end of the day unless site sampling requires that the machinery be decontaminated frequently. A separate decontamination pad may be required for heavy equipment.

Station 3: Physical Removal With Brushes And A Wash Basin

Prior to setting up Station 3, place plastic sheeting on the ground to cover areas under Station 3 through Station 10.
Fill a wash basin, a large bucket, or child's swimming pool with non-phosphate detergent and tap water. Several bottle and bristle brushes to physically remove contamination should be dedicated to this station . Approximately 10 - 50 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 4: Water Basin

Fill a wash basin, a large bucket, or child's swimming pool with tap water. Several bottle and bristle brushes should be dedicated to this station. Approximately 10-50 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 5: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to contain the water during the rinsing process. Approximately 10-20 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 6: Nitric Acid Sprayers

Fill a spray bottle with 10% nitric acid. An acid rinse may not be required if inorganics are not a contaminant of concern. The amount of acid will depend on the amount of equipment to be decontaminated. Provide a 5-gallon bucket or basin to collect acid during the rinsing process.

Station 7: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to collect water during the rinsate process.

Station 8: Organic Solvent Sprayers

Fill a spray bottle with an organic solvent. After each solvent rinse, the equipment should be rinsed with distilled/deionized water and air dried. Amount of solvent will depend on the amount of equipment to decontaminate. Provide a 5-gallon bucket or basin to collect the solvent during the rinsing process.

Solvent rinses may not be required unless organics are a contaminant of concern, and may be eliminated from the station sequence.

Station 9: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to collect water during the rinsate process.

Station 10: Clean Equipment Drop

Lay a clean piece of plastic sheeting over the bottom plastic layer. This will allow easy removal of the plastic in the event that it becomes dirty. Provide aluminum foil, plastic, or other protective material to wrap clean equipment.

7.2.2 Decontamination Procedures

Station 1: Segregate Equipment Drop

Deposit equipment used on-site (i.e., tools, sampling devices and containers, monitoring instruments radios, clipboards, etc.) on the plastic drop cloth/sheet or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross contamination. Loose leaf sampling data sheets or maps can be placed in plastic zip lock bags if contamination is evident.

<u>Station 2</u>: <u>Physical Removal With A High-Pressure Washer (Optional)</u>

Use high pressure wash on grossly contaminated equipment. Do not use high- pressure wash on sensitive or non-waterproof equipment.

<u>Station 3</u>: <u>Physical Removal With Brushes And A Wash Basin</u>

Scrub equipment with soap and water using bottle and bristle brushes. Only sensitive equipment (i.e., radios, air monitoring and sampling equipment) which is waterproof should be washed. Equipment which is not waterproof should have plastic bags removed and wiped down with a damp cloth. Acids and organic rinses may also ruin sensitive equipment. Consult the manufacturers for recommended decontamination solutions.

<u>Station 4</u>: <u>Equipment Rinse</u>

Wash soap off of equipment with water by immersing the equipment in the water while brushing. Repeat as many times as necessary.

<u>Station 5</u>: <u>Low-Pressure Rinse</u>

Rinse sampling equipment with distilled/deionized water with a low-pressure sprayer.

<u>Station 6</u>: <u>Nitric Acid Sprayers (required only if metals are a contaminant of concern)</u>

Using a spray bottle rinse sampling equipment with nitric acid. Begin spraying (inside and outside) at one end of the equipment allowing the acid to drip to the other end into a 5-gallon bucket. A rinsate blank may be required at this station. Refer to Section 9.

<u>Station 7</u>: <u>Low-Pressure Sprayers</u>

Rinse sampling equipment with distilled/deionized water with a low-pressure sprayer.

<u>Station 8</u>: <u>Organic Solvent Sprayers</u>

Rinse sampling equipment with a solvent. Begin spraying (inside and outside) at one end of the equipment allowing the solvent to drip to the other end into a 5-gallon bucket. Allow the solvent to evaporate from the equipment before going to the next station. A QC rinsate sample may be required at this station.

<u>Station 9</u>: <u>Low-Pressure Sprayers</u>

Rinse sampling equipment with distilled/deionized water with a low-pressure washer.

<u>Station 10</u> : <u>Clean Equipment Drop</u>

Lay clean equipment on plastic sheeting. Once air dried, wrap sampling equipment with aluminum foil, plastic, or other protective material.

7.2.3 Post Decontamination Procedures

1. Collect high-pressure pad and heavy equipment decontamination area liquid and waste and store in appropriate drum or container. A sump pump can aid in the collection process. Refer to the Department of Transportation (DOT) requirements for appropriate containers based on the contaminant of concern.

2. Collect high-pressure pad and heavy equipment decontamination area solid waste and store in appropriate drum or container. Refer to the DOT requirements for appropriate containers based on the contaminant of concern.

3. Empty soap and water liquid wastes from basins and buckets and store in appropriate drum or container. Refer to the DOT requirements for appropriate containers based on the contaminant of concern.

4. Empty acid rinse waste and place in appropriate container or neutralize with a base and place in appropriate drum. pH paper or an equivalent pH test is required for

neutralization. Consult DOT requirements for appropriate drum for acid rinse waste.

5. Empty solvent rinse sprayer and solvent waste into an appropriate container. Consult DOT requirements for appropriate drum for solvent rinse waste.

6. Using low-pressure sprayers, rinse basins, and brushes. Place liquid generated from this process into the wash water rinse container.

7. Empty low-pressure sprayer water onto the ground.

8. Place all solid waste materials generated from the decontamination area (i.e., gloves and plastic sheeting, etc.) in an approved DOT drum. Refer to the DOT requirements for appropriate containers based on the contaminant of concern.

9. Write appropriate labels for waste and make arrangements for disposal. Consult DOT regulations for the appropriate label for each drum generated from the decontamination process.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITYASSURANCE/ QUALITY CONTROL

A rinsate blank is one specific type of quality control sample associated with the field decontamination process. This sample will provide information on the effectiveness of the decontamination process employed in the field.

Rinsate blanks are samples obtained by running analyte free water over decontaminated sampling equipment to test for residual contamination. The blank water is collected in sample containers for handling, shipment, and analysis. These samples are treated identical to samples collected that day. A rinsate blank is used to assess cross contamination brought about by improper decontamination procedures. Where dedicated sampling equipment is not utilized, collect one rinsate blank per day per type of sampling device samples to meet QA2 and QA3 objectives.

If sampling equipment requires the use of plastic tubing it should be disposed of as contaminated and replaced with clean tubing before additional sampling occurs.

10.0 DATA VALIDATION

Results of quality control samples will be evaluated for contamination. This information will be utilized to qualify the environmental sample results in accordance with the project's data quality objectives.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow OSHA, U.S. EPA, corporate, and other applicable health and safety procedures.

Decontamination can pose hazards under certain circumstances. Hazardous substances may be incompatible with decontamination materials. For example, the decontamination solution may react with contaminants to produce heat, explosion, or toxic products. Also, vapors from decontamination solutions may pose a direct health hazard to workers by inhalation, contact, fire, or explosion.

The decontamination solutions must be determined to be acceptable before use. Decontamination materials may degrade protective clothing or equipment; some solvents can permeate protective clothing. If decontamination materials do pose a health hazard, measures should be taken to protect personnel or substitutions should be made to eliminate the hazard. The choice of respiratory protection based on contaminants of concern from the site may not be appropriate for solvents used in the decontamination process.

Safety considerations should be addressed when using abrasive and non-abrasive decontamination equipment. Maximum air pressure produced by abrasive equipment could cause physical injury. Displaced material requires control mechanisms.

Material generated from decontamination activities requires proper handling, storage, and disposal. Personal Protective Equipment may be required for these activities.

Material safety data sheets are required for all decontamination solvents or solutions as required by the Hazard Communication Standard (i.e., acetone, alcohol, and trisodiumphosphate).

In some jurisdictions, phosphate containing detergents (i.e., TSP) are banned.

12.0 REFERENCES

Field Sampling Procedures Manual, New Jersey Department of Environmental Protection, February, 1988.

A Compendium of Superfund Field Operations Methods, EPA 540/p-87/001.

Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual, USEPA Region IV, April 1, 1986.

Guidelines for the Selection of Chemical Protective Clothing, Volume 1, Third Edition, American Conference of Governmental Industrial Hygienists, Inc., February, 1987.

Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, NIOSH/OSHA/USCG/EPA, October, 1985.

APPENDIX A

Table

Table 1. Soluble Contaminants and Recommended Solvent Rinse

TABLE 1 Soluble Contaminants and Recommended Solvent Rinse		
SOLVENT[1]	EXAMPLES OF SOLVENTS	SOLUBLE CONTAMINANTS
Water	Deionized water Tap water	Low-chain hydrocarbons Inorganic compounds Salts Some organic acids and other polar compounds
Dilute Acids	Nitric acid Acetic acid Boric acid	Basic (caustic) compounds (e.g., amines and hydrazines)
Dilute Bases	Sodium bicarbonate (e.g., soap detergent)	Acidic compounds Phenol Thiols Some nitro and sulfonic compounds
Organic Solvents [2]	Alcohols Ethers Ketones Aromatics Straight chain alkalines (e.g., hexane) Common petroleum products (e.g., fuel, oil, kerosene)	Nonpolar compounds (e.g., some organic compounds)
Organic Solvent[2]	Hexane	PCBs

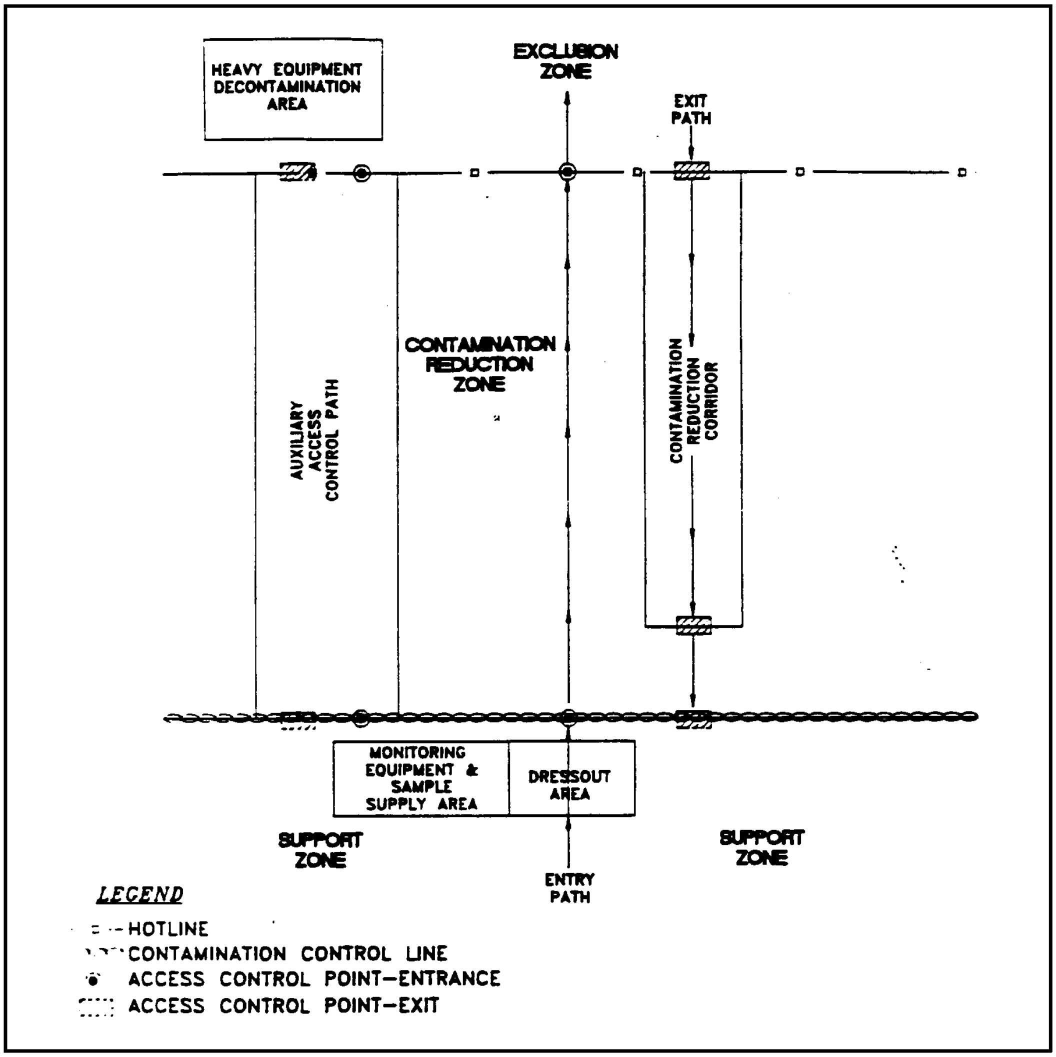
[1] - Material safety data sheets are required for all decontamination solvents or solutions as required by the Hazard Communication Standard

[2] - WARNING: Some organic solvents can permeate and/or degrade the protective clothing

APPENDIX B

Figures

Figure 1. Contamination Reduction Zone Layout



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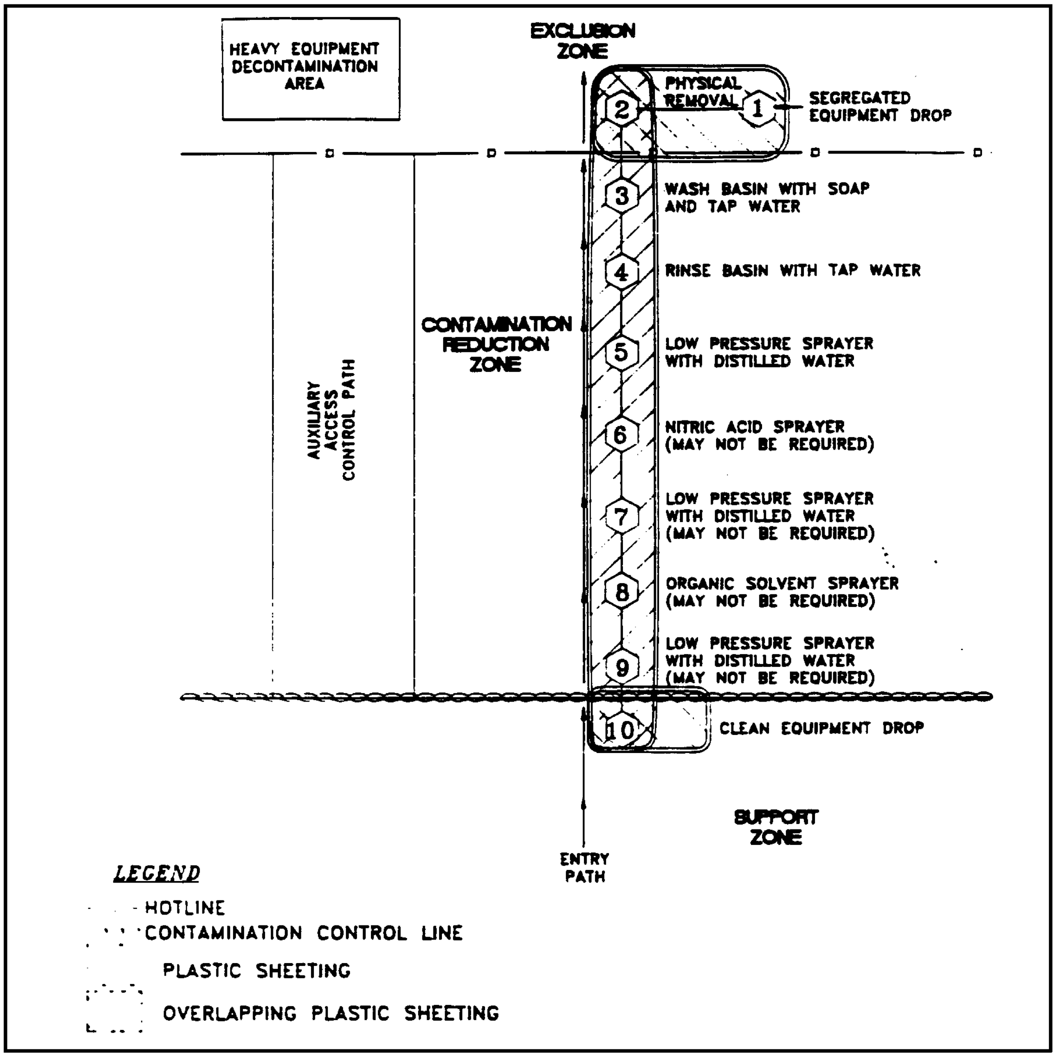
Figures

Figure 2. Decontamination Layout



4.0 CHIP, WIPE, AND SWEEP SAMPLING: SOP #2011

4.1 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) outlines the recommended protocol and equipment for collection of representative chip, wipe, and sweep samples to monitor potential surficial contamination.

This method of sampling is appropriate for surfaces contaminated with non-volatile species of analytes (i.e., PCB, PCDD, PCDF, metals, cyanide, etc.) Detection limits are analyte specific. Sample size should be determined based upon the detection limit desired and the amount of sample requested by the analytical laboratory. Typical sample area is 1 square foot. However, based upon sampling location, the area may need modification due to area configuration.

4.2 METHOD SUMMARY

Since surface situations vary widely, no universal sampling method can be recommended. Rather, the method and implements used must be tailored to suit a specific sampling site. The sampling location should be selected based upon the potential for contamination as a result of manufacturing processes or personnel practices.

Chip sampling is appropriate for porous surfaces and is generally accomplished with either a hammer and chisel, or an electric hammer. The sampling device should be laboratory cleaned and wrapped in clean, autoclaved aluminum foil until ready for use. To collect the sample, a measured and marked off area is chipped both horizontally and vertically to an even depth of 1/8 inch. The sample is then transferred to the proper sample container.

Wipe samples are collected from smooth surfaces to indicate surficial contamination; a sample location is measured and marked off. Sampling personnel wear a new pair of surgical gloves to open a sterile gauze pad, and then soak it with solvent. The solvent used is dependent on the surface being sampled. This pad is then stroked firmly over the sample surface, first vertically, then horizontally, to ensure complete coverage. The pad is then transferred to the sample container.

Sweep sampling is an effective method for the collection of dust or residue on porous or non-porous surfaces. To collect such a sample, an appropriate area is measured off. Then, while wearing a new pair of disposable surgical gloves, sampling personnel use a dedicated brush to sweep material into a dedicated dust pan. The sample is then transferred to the proper sample container.

Samples collected by all three methods are sent to the laboratory for analysis.

4.3 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Samples should be stored out of direct sunlight to reduce photodegredation and shipped on ice (4°C) to the laboratory performing the analysis. Appropriately-sized, laboratory-cleaned, glass sample jars should be used for sample collection. The amount of sample required is determined in concert with the analytical laboratory.

4.4 INTERFERENCES AND POTENTIAL PROBLEMS

This method has few significant interferences or problems. Typical problems result from rough porous surfaces which may be difficult to wipe, chip, or sweep.

4.5 EQUIPMENT/APPARATUS

- lab-clean sample containers of proper size and composition
- field and travel blanks
- site logbook
- sample analysis request forms
- chain of custody forms
- custody seals
- sample labels
- disposable surgical gloves
- sterile wrapped gauze pad (3 in. x 3 in.)
- appropriate pesticide (HPLC) grade solvent

- medium-sized, laboratory-cleaned paint brush
- medium-sized, laboratory-cleaned chisel
- autoclaved aluminum foil
- camera
- hexane (pesticide/HPLC grade)
- iso-octane
- distilled/deionized water

4.6 REAGENTS

Reagents are not required for preservation of chip, wipe or sweep samples. However, reagents will be utilized for decontamination of sampling equipment. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

4.7 PROCEDURES

4.7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or preclean equipment, and ensure that it is in working order.
4. Prepare scheduling and coordinate with staff, clients, and regulatory agencies, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site-specific health and safety plan.
6. Mark all sampling locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

4.7.2 Chip Sample Collection

Sampling of porous surfaces is generally accomplished by using a chisel and hammer or electric hammer. The sampling device should be laboratory cleaned or field decontaminated as per ERT SOP# 2006, Sampling Equipment Decontamination. It is then wrapped in cleaned, autoclaved aluminum foil. The sampler should remain in this wrapping until it is needed. Each sampling device should be used for only one sample.

1. Choose appropriate sampling points; measure off the designated area and photo document.
2. To facilitate later calculations, record surface area to be chipped.
3. Don a new pair of disposable surgical gloves.
4. Open a laboratory-cleaned chisel or equivalent sampling device.
5. Chip the sample area horizontally, then vertically to an even depth of approximately 1/8 inch.
6. Place the sample in an appropriately-prepared sample container with a Teflon-lined cap.
7. Cap the sample container, attach the label and custody seal, and place in a double plastic bag. Record all pertinent data in the site logbook. Complete the sampling analysis request form and chain of custody form before taking the next sample.
8. Store samples out of direct sunlight and cool to 4°C.
9. Leave contaminated sampling device in the sampled material, unless decontamination is practical.
10. Follow proper decontamination procedures, then deliver sample(s) to the laboratory for analysis.

4.7.3 Wipe Sample Collection

Wipe sampling is accomplished by using a sterile gauze pad, adding a solvent in which the contaminant is most soluble, then wiping a pre-determined, pre-measured area. The sample is packaged in an amber jar to prevent photodegradation and packed in coolers for shipment to the lab. Each gauze pad is used for only one wipe sample.

1. Choose appropriate sampling points; measure off the designated area and photo document.

2. To facilitate later calculations, record surface area to be wiped.

3. Don a new pair of disposable surgical gloves.

4. Open new sterile package of gauze pad.

5. Soak the pad with the appropriate solvent.

6. Wipe the marked surface area using firm strokes. Wipe vertically, then horizontally to ensure complete surface coverage.

7. Place the gauze pad in an appropriately prepared sample container with a Teflon-lined cap.

8. Cap the sample container, attach the label and custody seal, and place in a double plastic bag. Record all pertinent data in the site logbook. Complete the sampling analysis request form and chain of custody form before taking the next sample.

9. Store samples out of direct sunlight and cool to 4°C.

10. Follow proper decontamination procedures, then deliver sample(s) to the laboratory for analysis.

4.7.4 Sweep Sample Collection

Sweep sampling is appropriate for bulk contamination. This procedure utilizes a dedicated, hand-held sweeper brush to acquire a sample from a pre-measured area.

1. Choose appropriate sampling points; measure off the designated area and photo document.

2. To facilitate later calculations, record the surface area to be swept.

3. Don a new pair of disposable surgical gloves.

4. Sweep the measured area using a dedicated brush; collect the sample in a dedicated dust pan.

5. Transfer sample from dust pan to sample container.

6. Cap the sample container, attach the label and custody seal, and place in a double plastic bag. Record all pertinent data in the site logbook. Complete the sampling analysis request form and chain of custody form before taking the next sample.

7. Store samples out of direct sunlight and cool to 4°C.

8. Leave contaminated sampling device in the sample material, unless decontamination is practical.

9. Follow proper decontamination procedures, then deliver sample(s) to the laboratory for analysis.

4.8 CALCULATIONS

Results are usually provided in mg/g, μg/g or another appropriate weight per unit weight measurement. Results may also be given in a mass per unit area.

4.9 QUALITY ASSURANCE/ QUALITY CONTROL

The following general quality assurance procedures apply:

- All data must be documented on standard chain of custody forms, field data sheets or within the site logbook.

- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

The following specific quality assurance activities apply to wipe samples:

- A blank should be collected for each sampling event. This consists of a sterile gauze pad, wet with the appropriate solvent, and placed in a prepared sample container. The blank will help identify potential introduction of contaminants via the sampling methods, the pad, solvent or sample container.

- Spiked wipe samples can also be collected to better assess the data being generated. These are prepared by spiking a piece of foil of known area with a standard of the analyte of choice. The solvent containing the standard is allowed to evaporate, and the foil is wiped in a manner identical to the other wipe samples.

Specific quality assurance activities for chip and sweep samples should be determined on a site-specific basis.

4.10 DATA VALIDATION

Review the quality control samples and use the data to qualify the environmental results.

4.11 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA and specific health and safety procedures.

SOIL SAMPLING

SOP#: 2012
DATE: 11/16/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to describe the procedures for the collection of representative soil samples. Analysis of soil samples may determine whether concentrations of specific pollutants exceed established action levels, or if the concentrations of pollutants present a risk to public health, welfare, or the environment.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Soil samples may be collected using a variety of methods and equipment. The methods and equipment used are dependent on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type. Near-surface soils may be easily sampled using a spade, trowel, and scoop. Sampling at greater depths may be performed using a hand auger, continuous flight auger, a trier, a split-spoon, or, if required, a backhoe.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Chemical preservation of solids is not generally recommended. Samples should, however, be cooled and protected from sunlight to minimize any potential reaction.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary interferences or potential problems associated with soil sampling. These include cross contamination of samples and improper sample collection. Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Improper sample collection can involve using contaminated equipment, disturbance of the matrix resulting in compaction of the sample or inadequate homogenization of the samples where required, resulting in variable, non-representative results.

5.0 EQUIPMENT/APPARATUS

Soil sampling equipment includes the following:

- Sampling plan
- Maps/plot plan
- Safety equipment, as specified in the Health and Safety Plan
- Survey equipment
- Tape measure
- Survey stakes or flags
- Camera and film
- Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
- Appropriate size sample containers
- Ziplock plastic bags
- Logbook
- Labels
- Chain of Custody records and seals
- Field data sheets
- Cooler(s)
- Ice
- Vermiculite
- Decontamination supplies/equipment
- Canvas or plastic sheet
- Spade or shovel

- Spatula
- Scoop
- Plastic or stainless steel spoons
- Trowel
- Continuous flight (screw) auger
- Bucket auger
- Post hole auger
- Extension rods
- T-handle
- Sampling trier
- Thin wall tube sampler
- Split spoons
- Vehimeyer soil sampler outfit
  - Tubes
  - Points
  - Drive head
  - Drop hammer
  - Puller jack and grip
- Backhoe

6.0 REAGENTS

Reagents are not used for the preservation of soil samples. Decontamination solutions are specified in the Sampling Equipment Decontamination SOP and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.

2. Obtain necessary sampling and monitoring equipment.

3. Decontaminate or pre-clean equipment, and ensure that it is in working order.

4. Prepare schedules, and coordinate with staff, client, and regulatory agencies, if appropriate.

5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.

6. Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations will be utility-cleared by the property owner prior to soil sampling.

7.2 Sample Collection

7.2.1 Surface Soil Samples

Collection of samples from near-surface soil can be accomplished with tools such as spades, shovels, trowels, and scoops. Surface material can be removed to the required depth with this equipment, then a stainless steel or plastic scoop can be used to collect the sample.

This method can be used in most soil types but is limited to sampling near surface areas. Accurate, representative samples can be collected with this procedure depending on the care and precision demonstrated by the sample team member. A stainless steel scoop, lab spoon, or plastic spoon will suffice in most other applications. The use of a flat, pointed mason trowel to cut a block of the desired soil can be helpful when undisturbed profiles are required. Care should be exercised to avoid use of devices plated with chrome or other materials. Plating is particularly common with garden implements such as potting trowels.

The following procedure is used to collect surface soil samples:

1. Carefully remove the top layer of soil or debris to the desired sample depth with a pre-cleaned spade.

2. Using a pre-cleaned, stainless steel scoop, plastic spoon, or trowel, remove and discard a thin layer of soil from the area which came in contact with the spade.

3. If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or

other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval or location into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.2 Sampling at Depth with Augers and Thin Wall Tube Samplers

This system consists of an auger, or a thin-wall tube sampler, a series of extensions, and a "T" handle (Figure 1, Appendix A). The auger is used to bore a hole to a desired sampling depth, and is then withdrawn. The sample may be collected directly from the auger. If a core sample is to be collected, the auger tip is then replaced with a thin wall tube sampler. The system is then lowered down the borehole, and driven into the soil to the completion depth. The system is withdrawn and the core is collected from the thin wall tube sampler.

Several types of augers are available; these include: bucket type, continuous flight (screw), and post-hole augers. Bucket type augers are better for direct sample recovery since they provide a large volume of sample in a short time. When continuous flight augers are used, the sample can be collected directly from the flights. The continuous flight augers are satisfactory for use when a composite of the complete soil column is desired. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of three feet.

The following procedure will be used for collecting soil samples with the auger:

1. Attach the auger bit to a drill rod extension, and attach the "T" handle to the drill rod.

2. Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter). It may be advisable to remove the first three to six inches of surface soil for an area approximately six inches in radius around the drilling location.

3. Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the hole. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding drill rods. It also facilitates refilling the hole, and avoids possible contamination of the surrounding area.

4. After reaching the desired depth, slowly and carefully remove the auger from boring. When sampling directly from the auger, collect the sample after the auger is removed from the boring and proceed to Step 10.

5. Remove auger tip from drill rods and replace with a pre-cleaned thin wall tube sampler. Install the proper cutting tip.

6. Carefully lower the tube sampler down the borehole. Gradually force the tube samplerinto soil. Care should be taken to avoid scraping the borehole sides. Avoid hammering the drill rods to facilitate coring as the vibrations may cause the boring walls to collapse.

7. Remove the tube sampler, and unscrew the drill rods.

8. Remove the cutting tip and the core from the device.

9. Discard the top of the core (approximately 1 inch), as this possibly represents material collected before penetration of the layer of concern. Place the remaining core into the appropriate labeled sample container. Sample homogenization is not required.

10. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the

caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly.

When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

11. If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and follow steps 3 through 11, making sure to decontaminate the auger and tube sampler between samples.

12. Abandon the hole according to applicable State regulations. Generally, shallow holes can simply be backfilled with the removed soil material.

7.2.3 Sampling at Depth with a Trier

The system consists of a trier, and a "T" handle. The auger is driven into the soil to be sampled and used to extract a core sample from the appropriate depth.

The following procedure will be used to collect soil samples with a sampling trier:

1. Insert the trier (Figure 2, Appendix A) into the material to be sampled at a 0° to 45° angle from horizontal. This orientation minimizes the spillage of sample.

2. Rotate the trier once or twice to cut a core of material.

3. Slowly withdraw the trier, making sure that the slot is facing upward.

4. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.4 Sampling at Depth with a Split Spoon (Barrel) Sampler

The procedure for split spoon sampling describes the collection and extraction of undisturbed soil cores of 18 or 24 inches in length. A series of consecutive cores may be extracted with a split spoon sampler to give a complete soil column profile, or an auger may be used to drill down to the desired depth for sampling. The split spoon is then driven to its sampling depth through the bottom of the augured hole and the core extracted.

When split spoon sampling is performed to gain geologic information, all work should be performed in accordance with ASTM D 1586-67 (reapproved 1974).

The following procedures will be used for collecting soil samples with a split spoon:

1. Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the head piece on top.

2. Place the sampler in a perpendicular position on the sample material.

3. Using a well ring, drive the tube. Do not drive past the bottom of the head piece or compression of the sample will result.

4. Record in the site logbook or on field data sheets the length of the tube used to penetrate the material being sampled, and the number of blows required to obtain this depth.

5. Withdraw the sampler, and open by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type should be recorded on the boring log. If a split sample is desired, a cleaned, stainless steel knife should be used to divide the tube contents in half, longitudinally. This sampler

is typically available in 2 and 3 1/2 inch diameters. However, in order to obtain the required sample volume, use of a larger barrel may be required.

6. Without disturbing the core, transfer it to appropriate labeled sample container(s) and seal tightly.

7.2.5 Test Pit/Trench Excavation

These relatively large excavations are used to remove sections of soil, when detailed examination of soil characteristics (horizontal, structure, color, etc.) are required. It is the least cost effective sampling method due to the relatively high cost of backhoe operation.

The following procedures will be used for collecting soil samples from test pit/trench excavations:

1. Prior to any excavation with a backhoe, it is important to ensure that all sampling locations are clear of utility lines, subsurface pipes and poles (subsurface as well as above surface).

2. Using the backhoe, a trench is dug to approximately three feet in width and approximately one foot below the cleared sampling location. Place excavated soils on plastic sheets. Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by OSHA regulations.

3. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.

4. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In many instances, samples can be collected directly from the backhoe bucket.

5. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

6. Abandon the pit or excavation according to applicable state regulations. Generally, shallow excavations can simply be backfilled with the removed soil material.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OHSA and corporate health and safety procedures.

12.0 REFERENCES

Mason, B.J., Preparation of Soil Sampling Protocol: Technique and Strategies. 1983 EPA-600/4-83-020.

Barth, D.S. and B.J. Mason, Soil Sampling Quality Assurance User's Guide. 1984 EPA-600/4-84-043.

U.S. EPA. Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods, Second Edition. 1984 EPA-600/4-84-076.

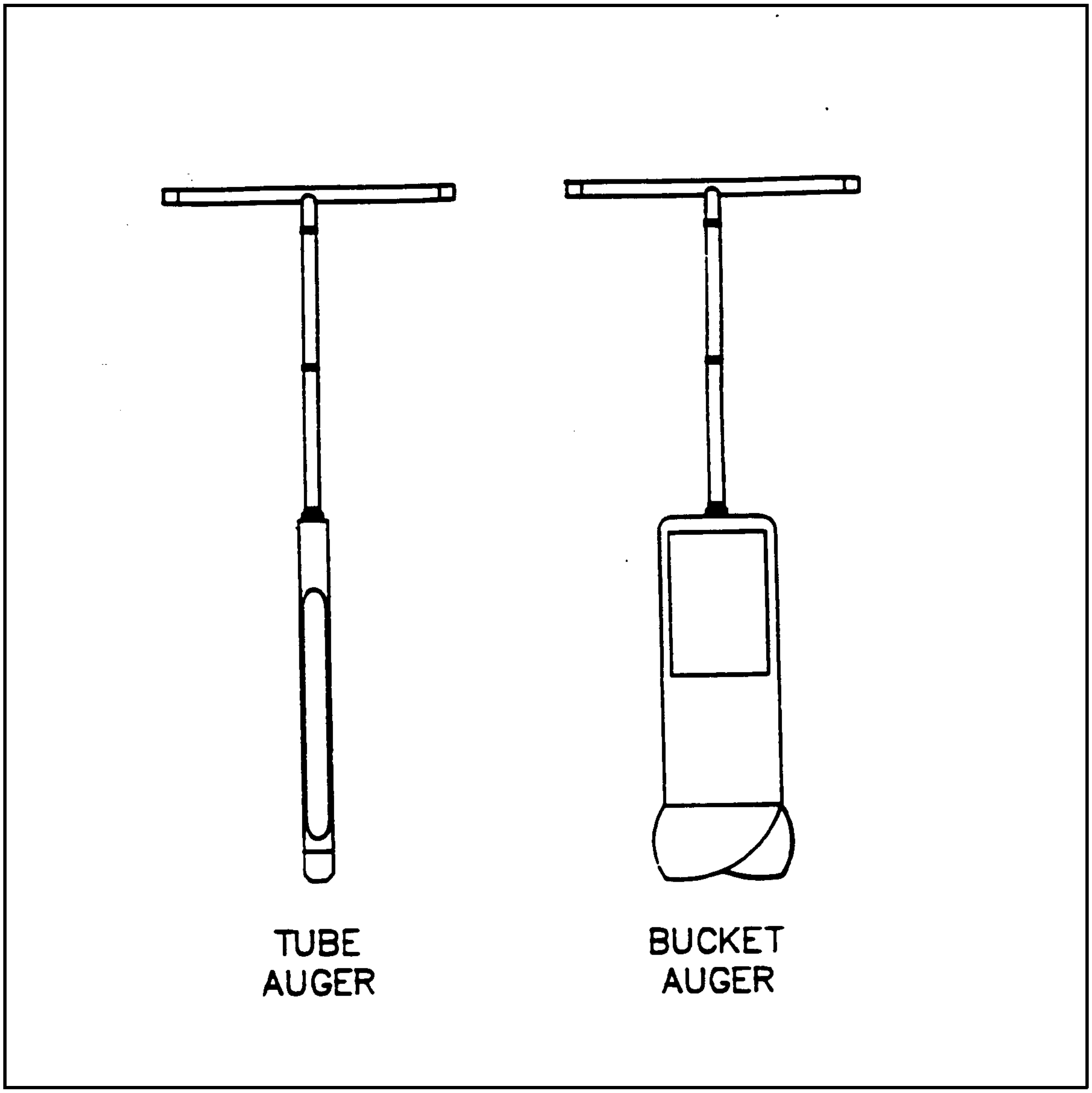
de Vera, E.R., B.P. Simmons, R.D. Stephen, and D.L. Storm. Samplers and Sampling Procedures for Hazardous Waste Streams. 1980 EPA-600/2-80-018.

ASTM D 1586-67 (reapproved 1974), ASTM Committee on Standards, Philadelphia, PA.

APPENDIX A

Figures

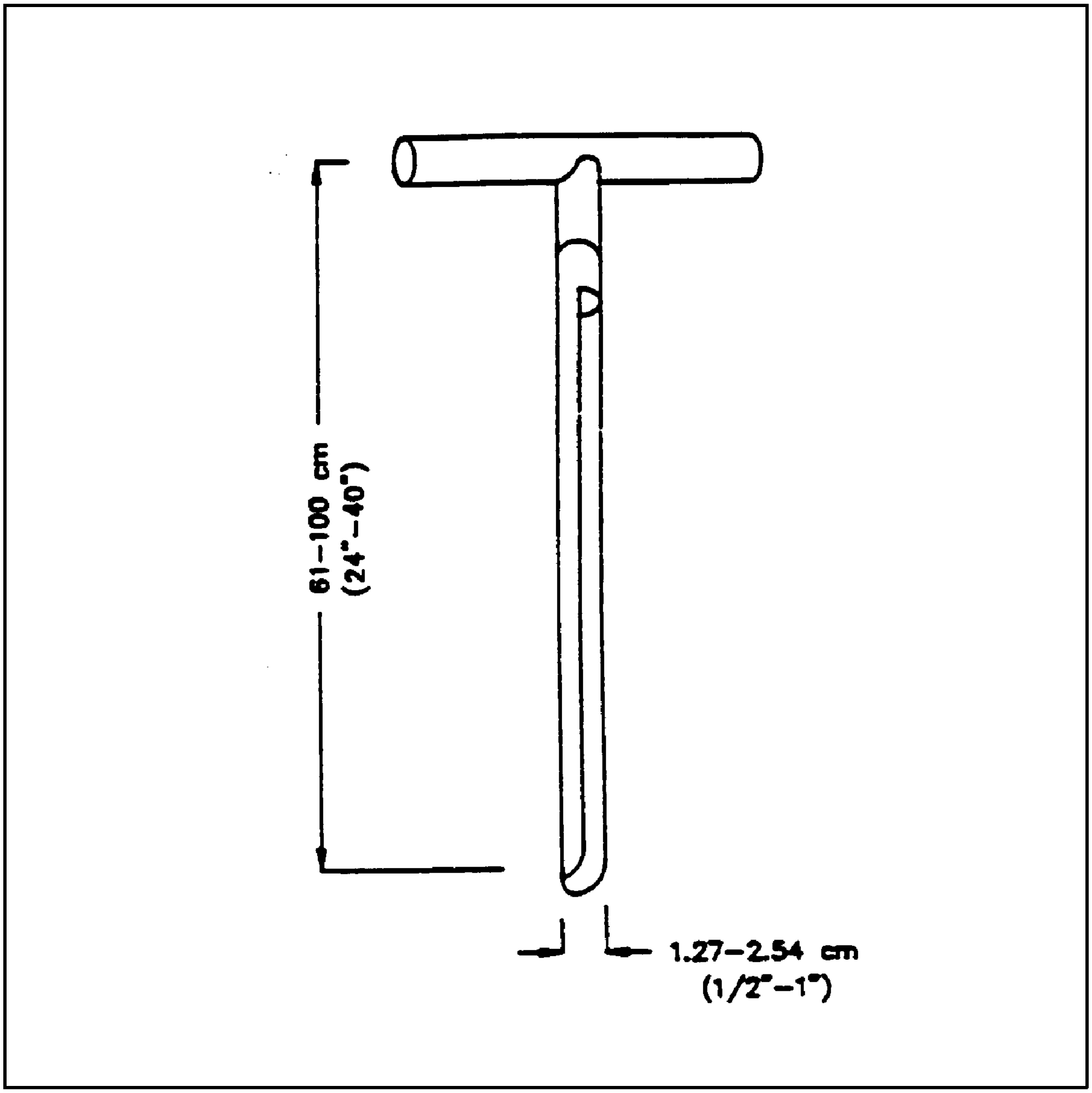
FIGURE 1. Sampling Augers



APPENDIX A (Cont'd)

Figures

FIGURE 2. Sampling Trier



WROP-100-03
OPERATION OF LUDLUM SCALERS WITH LUDLUM MODEL 43-10 ALPHA TRAY COUNTER

1.0 PURPOSE

This procedure describes the method used for analyzing wipe samples for removable gross alpha contamination resulting from the remediation activities at the DuPont Deepwater Project.

Scope. Removable alpha contamination measurements are required as the result of a variety of activities during the Project remediation. The process of collecting a smear involves Radiation Protection Technicians (RPTs) wiping a potentially contaminated area of 100 square centimeters (cm^2) with a clean, dry filter paper or similar media. WROP-04-410 and WROP-04-411 describe the specific procedures for the collection of smear samples. The smear is dried (if necessary) and counted by the RPT in a Ludlum Model 43-10 alpha tray counter linked to a Model 2000 scaler or equivalent. Counting times will be based on counting statistics and associated parameters, in accordance with WROP-03-300. All counting times shall be approved by the Radiation Safety Manager (RSM).

Potential applications of this procedure include the following:

- Items taken into radiological control areas that do not have surfaces that may be readily surveyed with a portable survey detector.
- Items shown to have total surface alpha contamination level exceeding the surface activity guidelines that may be found in Attachment 100-03-1.
- Items that are to be released from the site for unrestricted use.

The following activities are described in Section 4.0 of this procedure:

4.1 General

4.2 Determination of Background

4.3 Survey Requirements

4.4 Collection of Wipe Samples

4.5 Counting of Wipe Samples.

2.0 REFERENCES

WESTON Radiological Operations Procedure WROP-04-425, “Radiological Survey Documentation.”

WESTON Radiological Operations Procedure WROP-03-300, “Portable Radiation Monitoring Instruments Operation.”

WESTON Radiological Operations Procedure WROP-04-410, “Radioactive Contamination Surveys.”

WESTON Radiological Operations Procedure WROP-04-411, “Contamination Surveys of Materials, Equipment, and Portable Facilities to be Released for Unrestricted Use.”

WESTON Radiological Operations Procedure WROP-04-412, “Free Release of Heavy Equipment.”

WESTON “Radiation Safety Program Manual.”

DuPont Deepwater Project “Site Health and Safety Plan” (HASP).

3.0 GENERAL

3.1 Equipment

- Ludlum Model 43-10 Alpha Tray Counter
- Ludlum Model 2000 Scaler or equivalent scaler/ratemeter
- Smears or wipe sampling media
- Planchets (stainless steel or aluminum)
- Tweezers
- Forms from WROP-04-425
- Appropriate alpha check source
- Hand-held calculator
- Approved cleaning solution (i.e., distilled water)
- Q-tip cleaning swabs

3.2 Safety Considerations

All work activities performed under this procedure shall be in accordance with the Project HASP and the Radiation Safety Program Manual.

3.3 Responsibilities

3.3.1 RSM is responsible for:

- Ensuring that RPTs are qualified to perform this procedure.
- Reviewing, approving, and transmitting the documentation generated during the performance of this procedure.
- Maintaining knowledge of the contents of the operating procedures affecting the conduct of contamination surveys, and communicating the pertinent requirements to the RPTs performing this procedure.
- Ensuring that RPTs are trained regarding this procedure.

3.3.2 RPTs are responsible for:

- Performing contamination wipe sample analysis in accordance with this procedure.
- Discussing specific project contamination survey requirements with the RSM. If an RPT is unable to perform this procedure due to errors, extenuating circumstances, or any other reason, the RPT shall immediately stop and notify the RSM. All changes in sampling and survey protocol must be documented in field logbooks and on appropriate survey forms.

3.4 Prerequisites

Personnel shall be properly trained in the performance of this procedure prior to independent performance, as required by pertinent Radiation Safety Training procedures and project protocols.

3.5 Records

All records generated by this procedure are used in the Project Radiation Safety Program to document contamination levels of work areas and materials onsite. The records are stored, arranged, indexed, retrieved, scheduled, retained, and disposed of in accordance with WROP-04-425 and the Project Recordkeeping Procedures.

3.6 Precautions and Limitations

Not applicable.

3.7 Revisions

All revisions shall be controlled by the RSM.

3.8 Other

Section 4.0 of this procedure implements requirements of 10 Code of Federal Regulations (CFR) 835.404.

4.0 PROCEDURE

4.1 General

4.1.1 Ensure that the Ludlum Model 2000/ Model 43-10 has been subject to a operation function check in accordance with WROP-03-300.

> **Note:** Operation instructions for the Ludlum Model 2000 may be found in Attachment 23 of WROP-03-300.

4.1.2 Check with the RSM to ensure that the proper counting time has been specified.

4.1.3 Obtain the appropriate radiological survey data form and complete the introductory information. A sample form is included as Attachment 2 of WROP-04-425.

4.1.4 Before counting a sample, clean the tray and the counting chamber using a swab dampened with an approved cleaning solution (i.e., distilled water). Ensure that enough time has past to allow the tray and chamber to dry before attempting to count a survey. The tray and chamber should be cleaned daily at a minimum.

4.2 Determination of Background

4.2.1 Count an unused wipe sample for the specified counting time.

> **Note:** Instrument background may change throughout the day. Background counts should be collected at a minimum of two times per day. Preferably one background count should be collected at the time of the operational function check and then one count should be collected 4 to 5 hours later.

4.2.2 Record the background count in the appropriate column of the radiological survey sheet.

4.3 Survey Requirements

4.3.1 Survey requirements for samples to be counted in accordance with this procedure are contained in the Project RWPs, Operating Plan Guidance Manual, Sampling and Analysis Plan (SAP), HASP, Radiation Safety Program Manual, Waste Management Plan, and other Radiological Operations Procedures.

4.4 Collection of Wipe Samples

4.4.1 Techniques and procedures for performing contamination surveys using wipes and smears may be found in WROP-04-410, -411, and -412.

4.5 Counting of Wipe Samples.

4.5.1 Obtain a wipe sample from the sample in-box and record the sample number and the sample description on the Radiological Survey Form.

4.5.2 Place the wipe sample in a planchet.

4.5.3 Open the counting chamber and place the planchet containing the wipe sample into the sample tray.

4.5.4 Slide the tray under the detector until a click is heard. The click is the activation of a switch that applies high voltage to the detector (essentially it is the detector on/off switch). Gently turn the tray lock knob towards you, just enough to hold the tray in place.

Caution:	Do not over tighten the tray lock knob!!

4.5.5 Depress the count switch. A red light should appear designating that a count is in progress. Count each wipe sample for the period of time determined by the RSM.

Note:	The counting time for the wipe sample analysis should be equal to the background count time.

4.5.6 The count light going out designates the completion of the counting time. Record the gross counts on the radiological survey form and calculate the contamination values based on the detector efficiency and the background.

4.5.7 Immediately notify the RSM if a sample result is found to be greater than the surface activity guidelines found in Attachment 100-03-1.

4.5.8 Forward the completed Radiological Survey Form to the RSM for review and filing.

5.0 ATTACHMENTS

Attachment 100-03-1 Surface Activity Guidelines

WROP-100-03
TABLE OF CONTENTS

ATTACHMENT 100-03-1
SURFACE ACTIVITY GUIDELINES

ATTACHMENT 100-03-1
SURFACE ACTIVITY GUIDELINES
ALLOWABLE TOTAL RESIDUAL SURFACE ACTIVITY ($dpm/100cm^2$)[4]

Radionuclides[5]	Average[6][7]	Maximum[8][9]	Removable[9]
Group 1 - Transuranics, I-125, I-129, Ac-227, Ra-226, Ra-228, Th-228, Th-230, Pa-231	100	300	20
Group 2 - Th-natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232	1,000	3,000	200
Group 3 - U-natural, U-235, U-238, and associated decay products, alpha emitters.	5,000	15,000	1,000
Group 4 - Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous[10] fission) except Sr-90 and others noted above	5,000	15,000	1,000
Tritium (applicable to surface and subsurface)[11]	N/A	N/A	10,000

Source: Table and notes from "Response to Questions and Clarification of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material)," November 17, 1995.

(4) As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

(5) Where surface contamination by both alpha- and beta-gamma emitting radionuclides exists, the limits established for alpha- and beta-gamma emitting radionuclides should apply independently.

(6) Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

(7) The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

(8) The maximum contamination level applies to an area of not more than 100 cm^2.

(9) The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

(10) This category of radionuclides includes mixed fission products, including Sr-90 that is present in them. It does not apply to Sr-90 that has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

(11) Property recently exposed or decontaminated, should have measurements (smears) taken at regular time intervals to ensure that there is not a build-up of contamination over time. Because tritium typically penetrates the material it contacts, the surface guidelines in group 4 are not applicable to tritium. The Department has reviewed the analysis conducted by the DOE Tritium Surface Contamination Limits Committee ("Recommended Tritium Surface Contamination Release Guides," February 1991), and has assessed potential doses associated with the release of property containing residual tritium. The Department recommends the use of the stated guideline as an interim value for removable tritium. Measurements demonstrating compliance of the removable fraction of tritium on surfaces with this guideline are acceptable to ensure that non-removable fractions and residual tritium in mass will not cause exposures that exceed DOE dose limits and constraints.

WROP-08-810
LAND AREA GAMMA SURVEYS USING NAI DETECTORS

1.0 PURPOSE

The purpose of this procedure is to provide guidance to Radiological Protection Technicians (RPTs) in performing area scan surveys using NaI detectors. This procedure specifically applies to scanning surveys on open land areas, but may be useful for other land survey situations.

The following activities are described in Section 4.0 of this procedure:

- 4.1 Survey Setup and Background Determination
- 4.2 Survey Techniques
- 4.3 Follow-Up Actions

2.0 REFERENCES

U.S. Department of Energy (DOE). "Environmental Implementation Guide for Radiological Survey Procedures," Draft, November, 1992.

WESTON "Radiation Safety Program Manual."

WESTON Radiological Operations Procedure WROP-03-300, "Portable Radiation Monitoring Instrument Operation."

WESTON Radiological Operations Procedure WROP-04-425, "Radiological Survey Documentation."

3.0 GENERAL

3.1 Equipment

- Eberline ESP-2 (or equivalent) with 2x2 NaI detector.
- Ludlum Model 2221 (or equivalent) with Ludlum 44-10 2x2 NaI detector.
- Collimated Shield

3.2 Safety Considerations

All work activities performed under this procedure shall be in accordance with the Project HASP and the Radiation Safety Program Manual.

3.3 Responsibilities

3.3.1 The Radiation Safety Manager (RSM) is responsible for:

- Assuring that RPTs are qualified to perform this procedure and are documented as such.
- Reviewing and approving all survey documentation generated as a result of this procedure.
- Assuring that training on this procedure is developed, kept up-to-date, and offered to RPTs needing it. The RSM is also responsible for documentation of training completion.

3.3.2 RPTs are responsible for:

- Following this procedure. If unable to follow this procedure due to mistakes, extenuating circumstances, or for any other reason, the RPT shall immediately stop and notify the RSM.

3.4 Prerequisites

3.4.1 Prior to surveying, determine the survey pattern to be used, and the percent coverage necessary for the site. This may be in the form of a grid, survey transects, or discreet survey points, depending on the site size, topography, and other variables. The pattern, and percent coverage, should be in the SAP. When possible, deviations to the plan should be reviewed with the requester prior to making the change. When this is not practical, note any deviations in the survey remarks for later review.

3.4.2 Prior to use each day, perform an operational function check of the instrument(s), in accordance with WROP-03-300.

3.4.3 With the guidance of the RSM, determine the mode of ESP-2 operation/Ludlum Model 2221 or equivalent for the survey to be performed (i.e., ratemeter or scaler mode).

> **Note:** Using the ESP-2/Ludlum Model 2350 data-logging functions, and the “"Scaler/Average Rate” mode (30 second count times), can significantly reduce the amount of recordkeeping required in the field; however, care must still be taken to keep track of survey locations vs. data storage locations.

When the equipment and procedures are available, and if required, a correlation between NaI counts per minute (cpm) and μR/hr, using a Pressurized Ion Chamber (PIC), may be performed in accordance with WROP-100-17. This correlation should be performed in a radiation field similar to the field of interest (i.e., background, depleted uranium, Cs-137, etc.) for greatest accuracy.

3.5 Records

Radiological survey records are generated during the process of implementing this procedure. The original of the records is the record copy for the Project. The record copy is given to the RSM for processing, including arrangement and filing. Copies of the records may be made for information purposes.

These records are used by the project to document radiological surveys.

The records are stored, arranged, indexed, retrieved, scheduled, retained, and disposed of in accordance with the Project Recordkeeping Procedures and file system.

3.6 Precautions and Limitations

The results of this screening alone should not be used to determine protective clothing, respiratory protection, or waste management requirements, but should be used as a screening tool to indicate the need for additional surveys or analysis.

3.7 Revisions

Not applicable.

4.0. PROCEDURE

4.1 Survey Setup and Background Determination

4.1.1 Mark the land area to be surveyed so that the desired survey pattern can be achieved. A compass and tape measure are recommended for this purpose. Markings may be in the form of pin flags, paint markings (environmentally safe) on the ground, fence posts/wooden lath, or natural or man-made landmarks. Whenever possible, reference distances and compass directions from at least one natural landmark or building so that the survey can be reproduced, if necessary, at a later date.

4.1.2 Perform ESP-2/Ludlum 2221 or equivalent setup for the correct detector and mode of operation (as determined in step 3.4) in accordance with WROP-03-300.

4.1.3 Perform a minimum of five one-minute integrated counts. If practical, perform at least one measurement outside of each site boundary (approx. north, south, east, and west), with the detector at ground level.

4.1.4 Record the background readings on the Background Determination Log (Attachment 1).

4.1.5 Average the four (or more) readings to establish background for the area, and record on the Background Determination Log and Radiological Survey Form.

4.1.6 Calculate the action level (A.L.) at one-and one-half (1.5) times the mean background and record on the Background Determination Log. A lower A.L. may be established, at the RPT's discretion, if the area background measurements are very consistent. This shall be noted in the Comments section of the Background Determination Logsheet.

4.2 Survey Techniques

4.2.1 Operate the survey instrument in accordance with WROP-03-300.

4.2.2 Hold the probe approximately 2 inches above the ground surface.

4.2.3 Walking at a speed of approximately one to two feet per second, move the probe back and forth to cover a survey path approximately five to six feet wide. To help gauge your speed, a 1.5-meter (5-foot) wide by 10-meter long path should take about one minute. This survey rate will result in ten percent coverage, assuming that the detector will cover a path six inches wide (detector diameter plus two inches on either side).

> Note: The rate of forward progress should be adjusted based on the percent coverage desired.

4.2.4 Listen to the instrument audible response. Any detectable increase should be investigated.

4.2.5 Stop, back up, and slow down the survey speed to pinpoint the source.

4.2.6 If the audible increase cannot be reproduced, then proceed with the survey.

4.2.7 Record the elevated location, and the maximum reading obtained, on the survey map.

4.2.8 Perform and record a waist-high reading directly above the elevated location.

4.2.9 Record the survey results in accordance with WROP-04-425. In the Radiation Survey column of the Radiological Survey Form, line-out "mrem/hr", and write "cpm" in the heading.

4.2.10 If the scaler mode is used, then record, as a minimum, the highest count obtained on a given grid or transect, in addition to the alarm locations recorded previously.

4.2.11 If the ratemeter mode is used, then the survey results for a particular grid, or transect, may be recorded as "<X" (where X = A.L.), or as a range of readings if no detectable activity is found. Record all locations with detectable activity as in Step 4.2.9.

4.3 Follow-up Actions

Follow-up actions may include any or all of the following, depending on the situation. The actual follow-up to be performed should be discussed with the Project Manager and RSM.

4.3.1 In-situ gamma spectroscopy.

4.3.2 Soil sampling.

4.3.3 Dose rate measurements.

4.3.4 Surface contamination measurements.

5.0 ATTACHMENTS

Attachment 08-810-1	Background Determination Log
Attachment 08-810-2	Standard Deviation Formula

WROP-08-810
TABLE OF CONTENTS

ATTACHMENT 08-810-1
BACKGROUND DETERMINATION LOG

ATTACHMENT 08-810-1
BACKGROUND DETERMINATION LOG

Date: __________ Instrument Function checked ___ Yes ___ No

Project Location ______________________ RPT Signature ___________________________

Project Description:____

Inst. Type __________________ Inst. S/N __________________ Time __________________	Inst. Type __________________ Inst. S/N __________________ Time __________________	Inst. Type __________________ Inst. S/N __________________ Time __________________
Sample Location Sample #	Sample Location Sample #	Sample Location Sample #
Background Readings (units) 1) ____________________ 2) ____________________ 3) ____________________ 4) ____________________ 5) ____________________ 6) ____________________ 7) ____________________ 8) ____________________ 9) ____________________ 10) ____________________	Background Readings (units) 1) ____________________ 2) ____________________ 3) ____________________ 4) ____________________ 5) ____________________ 6) ____________________ 7) ____________________ 8) ____________________ 9) ____________________ 10) ____________________	Background Readings (units) 1) ____________________ 2) ____________________ 3) ____________________ 4) ____________________ 5) ____________________ 6) ____________________ 7) ____________________ 8) ____________________ 9) ____________________ 10) ____________________
Mean Background $\bar{X}$ =	Mean Background $\bar{X}$ =	Mean Background $\bar{X}$ =
Standard Deviation σ_{n-1} =	Standard Deviation σ_{n-1} =	Standard Deviation σ_{n-1} =
Action Level A.L. =	Action Level A.L. =	Action Level A.L. =
Comments	Comments	Comments

Note: Units always should be in counts/minute.

BACKGROUND DETERMINATION LOG

Date: __________ Instrument Function checked ___ Yes ___ No

Project Location ______________________ RPT Signature ____________________________

Project Description:____

Inst. Type ________________ Inst. S/N ________________ Time ________________	Inst. Type ________________ Inst. S/N ________________ Time ________________	Inst. Type ________________ Inst. S/N ________________ Time ________________
Sample Location Sample #	Sample Location Sample #	Sample Location Sample #
Background Readings (units) 1) ____________ 2) ____________ 3) ____________ 4) ____________ 5) ____________ 6) ____________ 7) ____________ 8) ____________ 9) ____________ 10) ____________	Background Readings (units) 1) ____________ 2) ____________ 3) ____________ 4) ____________ 5) ____________ 6) ____________ 7) ____________ 8) ____________ 9) ____________ 10) ____________	Background Readings (units) 1) ____________ 2) ____________ 3) ____________ 4) ____________ 5) ____________ 6) ____________ 7) ____________ 8) ____________ 9) ____________ 10) ____________
Mean Background $\bar{X}$ =	Mean Background $\bar{X}$ =	Mean Background $\bar{X}$ =
Standard Deviation σ_{n-1} =	Standard Deviation σ_{n-1} =	Standard Deviation σ_{n-1} =
Action Level A.L. =	Action Level A.L. =	Action Level A.L. =
Comments	Comments	Comments

Note: Units always should be in counts/minute.

ATTACHMENT 08-810-2
STANDARD DEVIATION FORMULA

ATTACHMENT 08-810-2
STANDARD DEVIATION FORMULA

Mean $\bar{x}$ -- average count obtained for the background samples -- the mean is calculated as shown below.

$$\bar{x} = \frac{(x_1 + x_2 + x_3 \ldots + x_n)}{n}$$

where

$\bar{x}$ = the mean of the background counts

n = number of samples

$(x_1 + x_2 + x_3 \ldots + x_n)$ = summation of count results for all background counts measured

Standard deviation (σ_{n-1}) — standard deviation of the mean is calculated as shown below:

$$\text{Standard deviation} = (\sigma_{n-1}) = \left[\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n-1} \right]^{1/2}$$

Units shall accompany calculations.

Action Levels (A.L.)

$$\frac{\textbf{Sample Screening A.L.}}{\bar{x} + 3\sigma_{n-1}}$$

$$\frac{\textbf{Area Surveys A.L.}}{\bar{x} \bullet 1\frac{1}{2}}$$

$$\frac{{}^{*}\textbf{Excavation Control A.L.}}{\bar{x} \bullet 2}$$

* Note geometry considerations when using this A.L. for excavation control. Wall gamma shine may cause false anomalies.

WROP-03-300
PORTABLE RADIATION MONITORING INSTRUMENT OPERATIONS

1.0 PURPOSE

The purpose of this procedure is to provide instructions on the response/source checking and basic operation of the portable hand-held radiation survey instruments used on the Project. Instructions are included for performing, documenting, and reviewing the source checks and for documenting instrument inventory and use.

Scope. This procedure applies to the Project radiation safety personnel who receive, use, decontaminate, and return portable radiation survey instruments to the WESTON Radiological Equipment Store (RES).

The following activities are described in Section 4.0 of this procedure:

4.1 Instrument Inventory

4.2 Pre-Operation Function Checks

4.3 Return Of Instruments

2.0 REFERENCES

NUREG/CR-5849, “Manual for Conducting Radiological Surveys in Support License Termination.”

U.S. Department of Energy (DOE), “Occupational Radiation Protection,” 10 Code of Federal Regulations (CFR) 835, November 1, 1993.

U.S. Department of Energy, “Radiological Control Manual,” DOE/EH-0256T, April 1994.

U.S. Department of Energy, “Radiation Protection For Radiation Workers,” DOE Order 5480.11, July 20, 1989.

U.S. Department of Energy, “Environmental Protection, Safety, and Health Protection Information Reporting Requirements,” DOE Order 5484.1, November 6, 1987.

U.S. Department of Energy, “Quality Assurance,” DOE Order 5700.6C, August 21, 1991.

U.S. Department of Energy, “Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels That Are Low As Reasonably Achievable (ALARA),” DOE/PNL-6577, July, 1988.

American National Standard, ANSI N323-1978, May 26, 1978, Section 4.6.

Various manufacturers’ (Ludlum, Eberline, Bicron, etc.) Instrument Technical Manuals.

DuPont Deepwater Project “Site Health and Safety Plan (HASP).”

3.0 GENERAL

3.1 Equipment

Radioactive sources of appropriate activity and isotope(s) for instrument(s) to be source checked.

See Attachments 03-300-3 through 03-300-32 for portable survey instruments.

3.2 Safety considerations

All sources should be controlled under the use of radiological work permits (RWPs).

Some of the sources used to perform instrument source checks have intense beta emission rates. Beta eye protection should be worn when using strong beta sources. Do not leave the source exposed longer than required.

All instruments shall be operated in accordance with the project HASP and Radiation Safety Program Plan Manual.

3.3 Responsibilities

3.3.1 Radiation Safety Manager (RSM) is responsible for:

- The implementation of this procedure.
- Assuring that the Radiological Protection Technicians (RPTs) are qualified to perform this procedure and are documented as such.
- Maintaining knowledge of the contents of this procedure.
- Periodic review of the documentation required by this procedure and for ensuring that completed source check logsheets are reviewed and forwarded to the Project file system.

3.3.2 Radiological Protection Technician are responsible for:

- The use of portable survey instruments in strict accordance with this procedure.
- Discussing specific project requirements with the RSM. If, for any reason, a RPT is unable to perform this procedure due to errors, extenuating circumstances, or any other reason, the RPT shall immediately stop and notify the RSM. All changes in protocol must be documented in the appropriate field log books and forms.

3.4 Prerequisites

Not applicable.

3.5 Records

Radiological survey and instrumentation records are generated during the process of implementing this procedure. The original of the records is the record copy for the Radiation Safety Program. The record copy is given to the RSM for initiating processing, including arrangement and filing. Copies of the records may be made for informational purposes.

The records are stored, arranged, indexed, retrieved, scheduled, retained, and disposed of in accordance with the Project Recordkeeping Procedures and file system.

3.6 Precautions and Limitations

Not applicable.

3.7 Revisions

Not applicable.

3.8 Other

Not applicable.

4.0 PROCEDURE

4.1 Instrument Inventory

4.1.1 New Issuance Instrument or Instrument Returned from Calibration

a. Upon receipt of an instrument, complete and sign the “Standard Laboratory Calibration Recall Notice” card (accompanies the instrument from WESTON) and return the card to WESTON RES.

b. Complete the instrument information on a “Portable Instrument Function Check” form (Attachment 03-300-1). The Aptec Model C7M Hand and Shoe Monitor “Function Check” checklist may be found in Attachment 03-300-32.

> **Note:** Attachment 1 may be modified to follow specific instrument check-offs, as needed.

c. Perform initial source check reading in accordance with Section 4.1.2.

4.1.2 New Issuance Instrument or Instrument Returned from Calibration

a. Determine the instrument response for each scale or decade normally used, and for which sources are available, as follows:

- Determine the source(s) and jigs required using Attachment 03-300-30 or -31.
- Record Source ID number.

- Select the desired scale on the instrument.
- Place the source in the specified position on the jig, as appropriate.
- Place the instrument/detector in the specific position on the jig.
- Allow sufficient time for the instrument to fully respond and the meter to stabilize.
- Observe the gross reading on the selected scale after response has stabilized.
- Move the detector away from the source.
- Repeat the previous four steps at least two times. If any one reading deviates from the average by more than 20%, obtain another reading to replace it.

b. Calculate and record on the logsheet the -20% and +20% values for the source, using the average value as the Reference Reading.

c. Complete Steps a. and b. for the remaining scales, sources and probes to be used.

Note: If there is any reason to suspect that the instrument is not responding properly to the source, contact the RSM for further guidance and possible return of the instrument to WESTON RES for evaluation.

d. Place the logsheet in the appropriate logsheet book or clipboard.

Note: Perform a new Initial Response when the response check source used is different than the original Initial Response check source.

e. Return sources and jigs to their storage locations.

4.2 Instrumentation Function Checks

4.2.1 Obtain the instrument to be used for the desired measurements using the guidance in Attachments 03-300-3 through-32.

a. Select the instrument based on the survey needs and:

- Detection capabilities for the type, energy, and intensity expected
- Interference from mixed radiation fields
- ALARA considerations
- Environmental conditions

b. Known conditions affecting survey instrumentation as a whole include:

- Ion chambers using reed switches for scale changing can malfunction when used in magnetic fields such as those found around rotating machinery, large electric motors, or any equipment containing magnetos.
- Large changes in altitude may impact instrument response. Evaluate the need to use correction factors on the observed instrument response.
- Use of ion chambers in very cold or very hot applications may require use of correction factors to correct the observed instrument response.
- Microprocessor based instrumentation is extremely susceptible to electrical changes. When using these instruments, exercise caution to preclude touching equipment which may be charged.
- Changing detector cable lengths may impact instrumentation signal response time.

c. Verify that the instrument calibration label is in place and indicates that the calibration has not expired.

d. Perform a battery check.

- Turn to each battery check position (for manual selection).
- Verify that the response is within the allowable limits.

e. For alpha scintillation probes, perform the following inspection:

- Remove the protective shield from the scintillation probe.
- Examine the detector window to ensure that it is not damaged. It must be free of holes and cracks for the instrument to operate properly. If there is any damage that cannot be repaired in the field, return the instrument for repairs.
- Replace the protective shield.

4.2.2 Checking physical condition of the instrument:

a. Record the date on the next available line in the “Daily/Prior to Use Physical/Source Check” section.

b. Examine the instrument for any physical damage.

- Check the body of the instrument (i.e. meter face for cracks, handle for damage, loose snaps).
- Check external cord for frays, cuts, shorts, loose wires and connections.
- Check detector surface for punctures or body damage on detector housing.

- Check the analog meter indicator to read “zero” or minimum indication in normal use position with power off.

c. Check that the instrument calibration label is in place and indicates that the calibration has not expired.

d. Perform a battery check.

- Turn to each battery check position (for manual selection).
- Verify that the response is within the allowable limits.

e. For alpha scintillation probes, perform the following inspection:

- Remove the protective shield from the scintillation probe.
- Examine the detector window to ensure that it is not damaged. It must be free of holes and cracks for the instrument to operate properly. If there is any damage that cannot be repaired while in the field, return the instrument for repairs.
- Replace the protective shield.

f. Perform a High Voltage check, if applicable.

g. Adjust the electronic zero of the instrument, if applicable.

4.2.3 Performing daily/prior to use function checks on portable instrumentation:

a. Obtain the source(s)/jigs listed on the logsheet(s) for the instrument(s) to be source checked.

b. Complete the next available line on the Portable Instrument Pre-Operational Source Check Sheet using the appropriate sources as follows:

- Turn the range selector switch to the appropriate scale for the source being used.
- Place the instrument and the source in the same geometry used for the initial (post-calibration) source check.
- Observe the gross check source reading on the selected scale after the instrument response has stabilized.

c. Repeat Step b. and c. for all the scales or decades normally used.

d. Record the reading in the appropriate block of the Function Check Log Sheet.

e. Compare all instrument readings with the appropriate Initial Reading to determine if they fall within ±20% of the Reference Readings.

- If any reading is not within ±20% of the Reference Reading, circle the reading and initial, inform the RSM and proceed to Section 4.3.1 of this procedure.
- Initial the appropriate block of the Source Check Sheet.

f. Plot the function check result (EFFICIENCY) on the Function Check Graph Log. Check the graph for out-of-range trends (Attachment 03-300-2).

4.2.4 Performing daily/prior to use functional check of the Aptec Model C7M Hand and Shoe Monitor.

a. Approach the C7M and observe the display panel. The "C7" message should be visible on the display.

b. While observing the display panel, step onto the foot grills. The foot symbols will illuminate, then go out. The "Push Hands In - Center Each Shoe" message and the hand symbols will be illuminated and remain on.

c. Insert the hands into the hand detector ports and push on the rear plates. The hand symbols will go out. The "Push Hands In - Center Each Shoe" message will go out and the "Counting" message will be illuminated.

d. Hold still until the counting cycle is completed. The "Clean" message should be illuminated.

e. Pull the hands back and then reinsert them to initiate another counting cycle. After the counting cycle has started, withdraw the left hand from the hand port. An audible alarm will sound and the "Removed Too Soon" message will be illuminated. The left hand symbol will also be illuminated.

f. Reinsert the left hand and press on the rear plate. The counting cycle will restart.

g. Repeat steps e and f for the right hand detector.

h. Repeat steps e and f for the left shoe detector.

i. Repeat steps e and f for the right shoe detector.

j. In order to ensure that the lamp system is functional, depress the "lamp Test" button on the bottom of the top section and hold it down. All of the display panel symbols should be illuminated.

k. Obtain a radioactive Beta check source of greater than 5, 000 dpm.

l. Place the calibration source in the left hand port. Initiate a counting cycle by positioning and the right hand and the shoes in place for counting. An audible alarm should sound and the left hand symbol, together with the "Contaminated" message, should be illuminated. The count rate will appear on the LCD display. Repeat this procedure for the right hand detectors, the left shoe detector, and the right shoe detector.

m. Complete the "Function Check" checklist contained in Attachment 03-300-32.

n. If any part of the function check is failed by the instrument, contact the RSM who will contact the RPTSD.

4.3 Return of Instruments

4.3.1 Perform a radiation and contamination survey on the instrument prior to release to the RES. For WESTON equipment, consult the RSM for decontamination procedures. Document the decontamination on the WESTON Return Material Decontamination Certificate.

4.3.2 Return radiation monitoring instruments to WESTON RES for calibration and repair

4.3.3 If, at any time, an instrument is damaged during use, fails any of the pre-operational check process, or is re-called from the instrument supplier:

- Attach an "Out of Service" tag to the instrument.
- Return the instrument to the RES.

4.3.4 Route the "Portable Instrument Pre-Operational Source Check Sheet" and "check lists" to the RSM, or designee.

5.0 ATTACHMENTS

Attachment 03-300-1	Portable Instrument Function Check Logsheet
Attachment 03-300-2	Function Check Graph Log
Attachment 03-300-3	MDA Calculation Work Sheet
Attachment 03-300-4	Operation of the ELECTRA with DP 6 Dual Scintillation Probe (**)
Attachment 03-300-5	Operation of the Xetex Model 501A (**)
Attachment 03-300-6	Operation of the Ludlum Model 2350 (**, WESTON)
Attachment 03-300-7	Operation of the Eberline Model RO-3C (**)
Attachment 03-300-8	Operation of the Eberline Model PIC-6B (**)
Attachment 03-300-9	Operation of the Eberline Model ESP-2 (**)

Attachment 03-300-10	Operation of the Eberline Model ASP-1 (**)
Attachment 03-300-11	Operation of the Ludlum Model 2221 with Ludlum Model 239-1F Floor Monitor (**, WESTON)
Attachment 03-300-12	Operation of the Bicron Model Micro Rem (**)
Attachment 03-300-13	Operation of the Bicron Model 2000 (**)
Attachment 03-300-14	Operation of the Eberline RM-14SA (**)
Attachment 03-300-15	Operation of the Eberline Model RM-20 (**)
Attachment 03-300-16	Operation of the XETEX 302B High Level Probe (**)
Attachment 03-300-17	Operation of the Bicron RSO-50 and RSO 500 (**)
Attachment 03-300-18	Operation of the Ludlum Model 12 (WESTON)
Attachment 03-300-19	Operation of the Ludlum Model 3 (WESTON)
Attachment 03-300-20	Operation of the Ludlum Model 9 (WESTON)
Attachment 03-300-21	Operation of the Ludlum Model 2200 (WESTON)
Attachment 03-300-22	Operation of the Ludlum Model 2220 (WESTON)
Attachment 03-300-23	Operation of the Ludlum Model 2000 (WESTON)
Attachment 03-300-24	Operation of the Ludlum Model 2300 (WESTON)
Attachment 03-300-25	Operation of the Ludlum Model 19 (WESTON)
Attachment 03-300-26	Operation of the Bicron Analyst (WESTON)
Attachment 03-300-27	Operation of the Bicron Labtech (WESTON)
Attachment 03-300-28	Operation of the Ludlum Model 2221 (WESTON)
Attachment 03-300-29	Operation of the Ludlum Model 77-3 (WESTON)
Attachment 03-300-30	** Radiation and Contamination Survey Instruments
Attachment 03-300-31	WESTON Radiation and Contamination Survey Instruments
Attachment 03-300-32	Operation of the Aptec Model C7M Hand and Shoe Monitor (**)

ATTACHMENT 03-300-18
OPERATION OF THE LUDLUM MODEL 12

ATTACHMENT 03-300-18
OPERATION OF THE LUDLUM MODEL 12

1. INSTRUMENT OPERATION

a. Examine the instrument for physical damage in accordance with Section 4.2.2. Do not use if damaged.

b. Check the instrument calibration sticker. Do not use if out of calibration.

c. Battery Installation

1) Slide the battery box button down. Open the lid and install two "D" size batteries. Note (+) (-) marks on the inside of the lid. Match the battery polarity to these marks.

2) Close the battery box lid.

> **Note:** Center post of flashlight battery is positive. Do not twist lid button - it slides to the rear.

d. Switch the range switch to BAT. The meter should deflect to the battery check portion of the meter scale. If the meter does not respond, recheck that the batteries have proper polarity. If meter deflection is within the battery check portion of the scale, the batteries are "OK."

e. Turn the instrument range multiplier switch to X1000. Expose the detector to a radiation check source. The speaker should click with the audio switch turned to the ON position.

f. Move the range switch to the lower scales until a meter reading is indicated. The toggle switch labeled F-S should have fast response if "F" position and slow response in "S" position.

g. Depress the RES switch. The meter should zero.

h. Select appropriate detector and attach to ratemeter with a standard "Type C" cable.

i. Complete source/response check in accordance with Section 4.2.3, if required.

j. Perform surveys in accordance with applicable WROPs.

> **Note:** When using M-12 with combination 44-3/42-9, the HV switch must be in the "N" position when using the 42-9 neutron detector, and in the "G" position when using the 44-38 energy-compensated GM-detector.

k. This ratemeter can be used with a variety of detectors. The most used detector models are Ludlum 44-9, 44-40, 44-10, 43-5, 44-38, and 42-9.

ATTACHMENT 03-300-19
OPERATION OF THE LUDLUM MODEL 3

ATTACHMENT 03-300-19
OPERATION OF THE LUDLUM MODEL 3

1. INSTRUMENT OPERATION

a. Examine the instrument for physical damage in accordance with Section 4.2.2. Do not use if damaged.

b. Check the instrument calibration sticker. Do not use if out of calibration.

c. Battery Installation

1) Slide the battery box button to the rear. Open the lid and install two "D" size batteries. Note (+) (-) marks on the inside of the lid. Match the battery polarity to these marks.

2) Close the battery box lid.

Note:	Center post of flashlight battery is positive. Do not twist lid button - it slides to the rear.

d. Switch the range switch to BAT. The meter should deflect to the battery check portion of the meter scale. If the meter does not respond, recheck that the batteries have proper polarity. If meter deflection is within the battery check portion of the scale, the batteries are "OK."

e. Connect the cable to the instrument and detector.

f. Turn the instrument range multiplier switch to X100. Expose the detector to a check source. The speaker should click with the audio ON-OFF switched to ON.

g. Move the range switch to the lower scales until a meter reading is indicated. The toggle switch labeled F-S should have fast response if "F" position and slow response in "S" position.

h. Depress the RES switch. The meter should zero.

i. Select appropriate detector and attach to ratemeter with a standard "Type C" cable.

j. Complete source/response check in accordance with Section 4.2.3. if required.

k. Perform surveys in accordance with applicable WROPs.

l. This ratemeter can be used with a variety of detectors. Most frequently used detectors are the Ludlum 44-9, 44-40, and 43-5.

ATTACHMENT 03-300-25
OPERATION OF THE LUDLUM MODEL 19

ATTACHMENT 03-300-25
OPERATION OF THE LUDLUM MODEL 19

1. INSTRUMENT OPERATION

a. Examine the instrument for physical damage in accordance with Section 4.2.2. Do not use if damaged.

b. Check the instrument calibration sticker. Do not use if out of calibration.

c. Battery Installation.

Note:	To open the Battery Lid, twist the lid button counterclockwise 1/4 turn. To close, twist clockwise 1/4 turn.

1) Open the lid and install two "D" size batteries. Note (+) (-) marks on the inside of the lid. Match the battery polarity to these marks.

Note:	Center post of flashlight battery is positive.

2) Close the battery box lid.

d. Adjust the audio AUD ON-OFF switch as desired.

e. Adjust the meter response F-S switch as desired.

f. Select the 0-5000 range with the Range Selector Switch.

g. Depress the BAT Test Button. Check the BAT TEST on the appropriate scale. Replace the batteries if the meter pointer is below the BAT TEST line.

h. Depress the Light Button (L). Check for light on the meter face.

i. Check the meter response in the "F" and "S" positions.

j. Check the audio indication with the AUD ON-OFF switch.

k. Check the instrument for the proper scale indication with a known source. Check all the ranges for the appropriate scale indication.

l. Depress the reset (RES) pushbutton. Check to see that the meter pointer returns to the zero position.

m. Complete source/resource check in accordance with Section 4.2.3 if required.

n. Perform surveys in accordance with applicable WROP.

ATTACHMENT 03-300-28
OPERATION OF THE LUDLUM MODEL 2221

ATTACHMENT 03-300-28
OPERATION OF THE LUDLUM MODEL 2221

1. INSTRUMENT OPERATION

a. Examine the instrument for physical damage in accordance with Section 4.2.2. Do not use if damaged.

b. Check the instrument calibration sticker. Do not use if out of calibration.

c. Battery Installation

1) Unscrew battery door latch at the end of instrument.

2) Install for "D" size batteries in the battery holder. The correct position of the batteries is indicated on the bottom of the battery door.

3) Depress battery button. The reading should not be less than 400.

d. Switch the power ON/OFF switch to the ON position. A random number will first be observed in the display, then 8.8:8.8:8:8. The third displayed number will be the program version. (At the time of this printing, program version is #261010.)

e. Press COUNT pushbutton. The display should zero. Two colons should appear on the display.

f. Press HOLD pushbutton. The colons should disappear.

g. Switch LAMP toggle switch to the ON position. LCD display backlighting and two lamps at the bottom of the analog meter should be illuminated.

> **Note:** If the lamp switch is left in the ON position for extended periods of time, battery life will decrease rapidly.

h. Check TEST pushbutton functions for proper operation.

i. Instrument and detector operating point is established by setting the probe voltage (HV) and instrument sensitivity (THR). For a given detector system, efficiency, background and noise are fixed by the physical makeup of the detector and rarely vary from unit to unit.

j. Select appropriate detector and attach the Labtech with a standard "MHV" type cable.

k. Make sure that all settings and adjustments have been properly made before turning on instrument.

l. Complete source/response check in accordance with Section 4.2.3 if required.

m. Perform surveys in accordance with applicable WROPs.